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MISSION CONTROL SYSTEMS EFFECTIVENESS ANALYSIS

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COMMUNICATIONS SYSTEM ANALYSIS

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ABSTRACT

This volume presents the analysis results, conclusions and recommendations derived from a study of the MCCH Communications System. The following three analyses were made:

1. Analysis of Inherent MDCS and PCM Telemetry Limitations and Analogous CCATS Limitations
2. Telemetry Data Handling Analysis
3. Communications Processor Loading Analysis

Specific analysis and conclusions with regard to system performance characteristics are discussed. Recommendations are made for extending and applying the analytic techniques used, and for initiating additional system studies.

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SECTION I

INTRODUCTION

SCOPE

The analysis results presented in this section reflect basic decisions in two areas concerning the scope of the Communications System portion of the overall Task A study. First of all, it was necessary to determine which of the seven existing communications subsystems should be included within the present study effort. Secondly, it was necessary to establish a ground rule concerning the inclusion of CCATS considerations as part of the study.

Regarding the selection of certain existing communications subsystems for analysis, the subsystems selected were those considered to have the greatest operational significance and, at least potentially, the most severe limitations in terms of performance and growth characteristics (limitations which may not be eliminated without significant expenditures of time and money). These are as follows:

1. Communication Processing Subsystem
2. Telemetry Subsystem (PCM portion thereof)
3. Master Digital Command Subsystem

The following subsystems have not been considered: Pneumatic Tube, Voice, Teletype and Facsimile, and Communications Facility and Controls (FACS).

Regarding consideration of CCATS within this study, the following ground rule was established: Emphasis would be placed on the existing system, but an attempt would be made to select existing system characteristics for analysis which, in addition to being significant in their own right, would produce results and/or involve analytic tools/techniques applicable at least in part to the long-term goal of a more comprehensive CCATS analysis. The application of this ground rule is discussed further in SECTION II.

GENERAL OBJECTIVES

The general objectives of this portion of the study may best be understood in light of two basic guidelines. These are as follows:

1. System characteristics are considered herein to warrant analysis only by virtue of being significant either in terms of system performance, primarily from an operational viewpoint, or in terms of system growth (or augmentation) capabilities. (Appendix A, in a more conceptual manner, discusses the categorization of all questions of interest regarding a system into those derived from either a performance or a growth orientation.)

2. "Effectiveness Analysis" for purposes of this report consists - rather than of an evaluation of present/predicted system characteristics in terms of present/predicted specific system requirements - of an analytic "description" of significant system characteristics.

Recognizing the above guidelines and the study scope as defined, general objectives may be delineated as follows:

1. Provide an analysis, quantitative to the extent possible, of significant performance and growth characteristics of the existing Communications System. This analysis should facilitate system evaluation by NASA.

2. Provide to the extent presently possible an analysis of, or at least a qualitative indication of, expected CCATS charactersitics analogous to those analyzed in more detail for the existing communications subsystem.

3. Develop or begin to develop a set of analytic tools and/or techniques considered useful for any on-going systems analysis/evaluation effort of the communications system.

More detailed objectives are presented in subsequent paragraphs for each portion of the analysis. Note that the provision of a general system description is not included as an objective of this report and therefore, that an understanding of the system at a general level on the part of the reader is assumed.

At this point, it might be noted that all of the conclusions and recommendations derived from the foregoing analysis may not be viewed as directly supporting the above objectives; certain conclusions/recommendations must be viewed as byproducts of pursuing these objectives.

BACKGROUND

General Approach

The objectives delineated above were pursued by considering any supporting analysis effort to be part of an overall effectiveness analysis without distinguishing between portions of the analysis requiring only straightforward tabulation of capability and capacity characteristics and portions requiring extensive theoretical and/or usage data analysis. In addition, primary emphasis was placed on the selection of significant characteristics for analysis; this emphasis resulted in a significant expenditure of effort for the selection process resulting in Appendix A as a study byproduct. Once selected, system characteristics were analyzed in a way considered most appropriate in light of the nature of the question of interest and the data available.

NASA Participation

It should be noted that, in addition to the necessary NASA support in obtaining and understanding system information, significant support was received in the areas both of selecting system characteristics considered significant for analysis and of successfully recording empirical communications processor loading data. The first area deserves emphasis in that the usefulness of any study of this kind is largely dependent upon which characteristics have been analyzed. The latter area is noted because the analyst's own degree of familiarity with facility scheduling procedures, program change procedures and test conduct procedures would not have permitted successful conduct of this portion of the analysis.

CONTENTS OF COMMUNICATIONS SYSTEM VOLUME

To assist the reader, a summary of the contents of the remainder of this volume of the final report follows:

Section II, Selection of System Characteristics for Analysis discusses the selection process in terms of the factors involved, the interaction between these factors, the characteristics selected, and some significant omissions in terms of characteristics not analyzed as part of this report.

Section III, Effectiveness Analysis constitutes the primary portion of the report - a description of specific analyses in terms of specific objectives, technical results, and any associated conclusions/recommendations. Note that this section is intended to contain sufficient technical information to permit an understanding of the results, conclusions, recommendations presented, but not sufficient information to permit detailed scrutiny or reconstruction of the results; such information may be found in Appendix B. Note also that any consideration of CCATS is "intermingled" with the discussion of the analogous characteristics of the existing system.

Section IV, Summary of Recommendations summarizes the study recommendations.

SECTION II

SELECTION OF SYSTEM CHARACTERISTICS FOR ANALYSIS

FACTORS INVOLVED AND THEIR INTERACTION

Based on the prior discussions of scope, objectives and general approach, certain factors would be expected to be involved in the selection of specific characteristics of the existing system for analysis. These two factors appear first below with a brief indication of how each was included in the selection process. Also as would be expected, factors identified in terms of hard and fast practical constraints were also involved; these appear below as the final two.

Significance of a Particular System Characteristic

Viewing significance from either a performance or an augmentation viewpoint, the methodology discussed in Appendix A was employed to derive a list of significant characteristics of the existing system from various types or categories of MCCH requirements. NASA comments were also obtained and discussed.

CCATS Applicability

As defined previously, this factor involves a determination or estimate of the extent to which the results, tools, and/or analytic techniques associated with analysis of an existing system characteristic will contribute as well to an analysis of CCATS. This factor was considered and discussed by NASA and MITRE personnel for characteristics being considered for analysis.

Availability of Usage Data

Considering usage data to consist of any data collected empirically, a survey of available data was conducted for the three subsystems of interest.

Available Time vs. Report Schedule

For each existing system characteristic of potential interest, an estimate was made of the time required to accomplish an associated analysis.

Consideration of the interaction between these factors led to a final determination of those specific system characteristics to be analyzed. This end product of the selection process was then reviewed with the appropriate NASA personnel to insure a common understanding of the content of the study on the part of all parties concerned. The following paragraph presents the results of the selection process.

SPECIFIC RESULTS OF SELECTION PROCESS

Characteristics To Be Analyzed

1. Inherent Limitations of MDCS and PCM Telemetry Hardware and Analogous Limitations for CCATS - Consideration of both MDCS and PCM Telemetry Hardware, particularly the Ground Station in the latter case, leads to the conclusion that certain basic design characteristics of this special-purpose hardware may be equated with potentially significant operational limitations. Despite the fact that this conclusion is certainly not original with this author, it was considered worthy of the effort involved to tabulate these characteristics in terms of their limitations on operational "parameters" and to present, to the extent possible as a function of CCATS design progress, a description of the analogous CCATS characteristics.

2. Time Delays and Sampling Rates Associated with Telemetry Data Handling - Such telemetry data handling characteristics of the existing system were selected for analysis primarily based 1) on the relatively critical nature of the timeliness of telemetry data when compared to other types of MCCH-processed data and 2) on the fact that telemetry data represents a high percentage of the "data volume" handled by the

MCCH and, therefore, is of great interest from an engineering point of view. "CCATS applicability" was considered a potential merit of such an analysis, but not as a prerequisite.

3. Communications Processor Loading - "Loading" as used in this case refers to usage of computing capacity in terms of the percentage of time a processor is busy performing software operations. Despite the fact that it is not possible at this time to perform a detailed loading analysis on the CCATS hardware/software configuration, such an analysis of the existing system was considered to have merit in terms both of achievable results and of the development of tools/techniques applicable to later CCATS analysis.

Important Characteristics Not Analyzed

Although there exist several areas not covered herein in which analysis could be performed relative to the MDCS and Telemetry Subsystems, these omissions are considered to be of limited importance in light of the forthcoming major CCATS augmentation. Similar reasoning mitigates any concern about the omission of certain characteristics of the existing Communications Processing configuration. Regarding the existing subsystems, therefore, any omissions from this analysis are considered to be of minor importance. Expanding one's scope of interest to include CCATS, however, one finds - as might be expected - significant areas begging further analytic work. Two such areas are discussed below.

Note that it is not intended to present a comprehensive list of all possible fruitful areas for future analysis which have not been covered in this report. For example, the issues of time delays incurred within the Communications Processor (or CCATS) for other than TLM data and of the RTCC-to-CCATS bit rate required to support various data requirements are potential areas of further useful analysis activity. Also results to date for certain aspects of the analyses reported in this volume must be considered incomplete and prliminary, meaning that further effort is required in these areas as well. The intent is simply to identify two areas of particular importance which were specifically encountered but not pursued during this study effort.

Analysis of CCATS Storage Utilization

In the case of any adaptation via software of a general-purpose hardware processing configuration to particular operational needs, a legitimate area for analysis is the utilization of both core and peripheral storage in terms of the types and quantities of data stored. Such analysis provides quantitative indications of the overall growth capability of the system, the ability to accommodate new functions, etc. Because little analysis in this area relative to CCATS could be accomplished with confidence at this time and because the expenditure of effort to pursue this area for the existing system did not appear warranted, no such analysis was undertaken. It is recommended that such an analysis be considered as soon as sufficient CCATS design information becomes available.

The Time Homogeneity Issue

In a data processing and transmission system where a cyclic or commutative scheme is used to sample data serially, the time homogeneity of a given parametric data sample is always of concern. Since commutative techniques are integral to the network design, time homogeneity will be an issue with CCATS. The analysis of the cycle sync portion of the time delays associated with TLM data handling is closely related to the data time homogeneity problem and the information developed will be useful in studying data homogeneity problems. Analysis of this characteristic of the communications system as related to CCATS design should be considered.

SECTION III

EFFECTIVENESS ANALYSIS

ANALYSIS OF INHERENT MDCS AND PCM TELEMETRY LIMITATIONS AND ANALOGOUS CCATS LIMITATIONS

Specific Objectives

If one is willing to accept this author's coining of the term "operational parameter" to refer to capabilities of the system having direct operational significance, the specific objective of this portion of the analysis may be stated as follows:

> To provide a comparative analysis, for each of several selected operational parameters related to command and telemetry data handling, of the MCCH system limitations associated both with the existing subsystems and with the CCATS configuration.

It should be noted that the term "limitation" does not necessarily connote inadequacy.

Supporting Technical Information

Selected technical information of a descriptive nature is provided in this subparagraph on the basis that the assumed general level of system understanding may not be adequate to permit a meaningful understanding of the analysis results.

MDCS Memory Sector Organization

Basic to an understanding of MDCS operation is the concept of a 1024-word memory divided into ten parts, designated "sectors", each of which may be considered fixed in terms of its length (number of words) and its location within the total memory. Although the MDCS hardware is not sensitive to the detailed characteristics of the commands employed for GEMINI, this hardware does require that only one word of memory be used for a single command. In addition, eight of the ten sectors permit initiation of their contents for transmission to be controlled by Flight Controller (FC) console modules: two of these permit selective initiation on a per word basis, (presently devoted to RTC storage) six of these require that the contents of the entire sector be transmitted in response to a single FC initiation action (command loads). In terms of the correlation between sectors and command sites, each command site (including only real-time sites as relevant to Flight Controller command initiation capabilities) is associated in a fixed manner with a set of Communication Processor interface hardware known as a Transmit Subsystem which, in turn, may transmit data from only two command load sectors and from either of the two sectors permitting selective command initiation.

CCATS Command Processing Concept

Controlling the nature of CCATS command processing is the overall Apollo command concept which has two basic interrelated characteristics: storage pre-pass or pre-mission of command data (individual commands or loads) in a Remote Site Command Processor (RSCP) and MCCH control of command "uplinking" by initiating transmission, rather than of the actual command data of interest, of an "execute" message which specifically designates the command data to be up-linked from the RSCP. Transmission of an "execute" message is achieved by a FC using a 6 x 3 matrix of Push-Button Indicators (PBI's) known as a Command Panel, each PBI on a given panel being associated with a particular "execute" message.

In terms of CCATS software implementation, the capability to associate each PBI on each panel with a unique command is provided in the form of an "execute table" for each command panel with a separate one word entry for each PBI. Each entry in an "executive table", rather than being sensitive in a fixed manner to the type of command data, the site, or vehicle with which it is associated, may be viewed as a programmable set of address bits associated on a mission-by-mission basis with the location of pre-stored command data at the RSCP.

PCM Telemetry Ground Station Characteristics

Little need be said about the ground stations for purposes of this analysis once it is recognized that this device must be viewed as a special-purpose stored program processor whose storage capacity, instruction repertoire and structure, register capabilities, display device interface hardware, etc., are specifically tailored to GEMINI program requirements.

CCATS Telmetry Decommutation Concept

The first step in decommutation is synchronizing to an incoming data stream at both Main Frame (MF) and Subframe levels. Main Frame synchronization is accomplished by the hardware or software recognition of specified bit patterns. Subframe synchronization is accomplished by software interpretation of "frame counts" within the MF content to determine which cycle of the MF is being received. (MF cycles as defined herein are equivalent to the number of MF transmissions required to describe the status of all telemetry parameters included within the format being received. The actual number of such transmissions is equal to the maximum subcommutation depth or ratio from a MF viewpoint.)

The next step in decommutation is the routing of telemetry data to specified destinations on a parameter-by-parameter basis. This is achieved by table look-up. In particular, each mission format may be associated with a set of decommutation tables. Each such set may be viewed as "N" tables where "N" is equal to the maximum subcommutation ratio and where each table consists of a single entry per parameter location within the format which designates the intended destination of that parameter.

All sets of decommutation tables, one set per format, are stored on drum and are used as follows: once synchronization at the subframe level has been accomplished, the particular decommutation table within the appropriate format set is addressed based on the frame count. This particular table is then read from drum into a core working area. From this point on, parameter routing occurs parameter-by-parameter on a table look-up basis.

CCATS Telemetry Display Driving

The CCATS configuration uses the existing PCM Ground Stations to provide display driving capability without fully employing the programmed decommutation feature of these devices. Specifically, the CCATS processor feeds decommutated telemetry data in serial bit stream form to the ground stations in a sequence which, when combined with a "fixed" ground station data routing program, results in the proper display destination for up to 125 events and 100 analogs. Additional CCATS event driving capability is achieved by interfacing CCATS with a set of Digital Display Drivers (DDD's).

Presentation and Discussion of Results

Results of this portion of the analysis are presented in Table 2-1. A discussion of these follows.

Sources of Data for Analysis

Various NASA system documentation and the MITRE descriptive diagrams resulting from Task A1 were consulted, the latter only as related to the existing system.

Comments to Clarify Presentation (See Table 2-1)

Indications of system characteristics for each operational parameter are limited to those characteristics considered primary in terms of limiting or constraining this parameter. In addition, limitations of the existing system, rather than being stated in GEMINI terminology, have been generalized to indicate such limitations in a basic form as inherent to the subsystem hardware or software.

TABLE 2-1 Operational Limitations of the Existing System and Analogous Limitations for the CCATS Configuration

OPERATIONAL PARAMETER	LIMITATIONS IMPOSED BY EXISTING SYSTEM	LIMITATIONS IMPOSED BY CCATS
For MDCS & CCATS Equivalent A. Number & Types of Commands Available for FC* Initiation (Not simultaneously) *Flight Controller	. 220 1-word commands capable of individual initiation . 3 command loads of up to 48 words . 3 command loads of up to 112 words Limiting factor: MDCS sector size allocation	Presently Specified Requirements: . A mix of up to approx. 300 commands of any type with both loads and individual commands each associated with 1 of the 300 possibilities (Derived from no. of command panels and no of command PBI's/panel) Upper Limit . Determined by core memory available for storage of "execute tables" . Not sensitive to command types
B. Number of Vehicles Supportable per Mission (Capable of being "commanded" from MCCH)	. 2 vehicles/mission Limiting factor: No of MDCS command load sectors allocated to each command site. (Assume each vehicle requires a separately addressable load type.)	Presently Specified Requirement . All Apollo vehicles (but vehicle distinction not relevant to software design in any significant way) Upper Limit . None uniquely associated with vehicle distinction, but constrained in terms of the max. no. of vehicles which may be supported by the total no. of commands permissible. Therefore, again return to issue of core available for "execute tables".
C. Number of Command Sites Associated with FC Initiation Capability	. 3 command sites Limiting factor: No. of MDCS transmit subsystems and associated sectors	Presently Specified Requirement . Up to 32 command sites (Derived assuming all combinations of 5 address bits) Upper Limit . None of practical interest

D. Number of Missions Capable of Being Simultaneously Supported	. Up to 2 simultaneous missions, any combination of simulated and operational *if* redundancy not required Limiting factor: 1 MDCS unit per mission required, 2 units	Presently Specified Requirement . Up to 2 simultaneous missions, any combination of simulated and operational without qualification. Upper Limit . Determined by both excess computing capacity and program/data storage capacity vs. demands of any additional missions
For PCM TLM Subsystem & CCATS Equivalent A. Format Characteristics Which may be Accommodated	a. 4 - 64 bit words b. Main Frame (MF) sync on pattern of 7-24 bits c. Subframe sync by Recycle Sync or ID Count methods For Recycle Sync - Up to two asynchronous subframes identified by patterns of 7-24 bits For ID Count - Up to two sets of synchronous subframes; 1 set limited to 64 subframes, other to 128 subframes d. Maximum MF length of 512 words or 4096 bits e. Maximum subcommutation ratio or "depth" of 200 from MF viewpoint Limiting factor: Software and hardware characteristics of PCM Ground Station	Presently Specified Requirement (or, in this case, any presently known implementation characteristics) Related to a, up to 15 bits/word Related to b, MF sync patterns of up to 3 10-bit sequences Related to c, ID count technique only; 1 set of synchronous subframes only with no unique limit on number of subframes/set Related to d, approx. 4000 words Related to e, no need to specify in practice except as related to decomm. table storage as discussed immediately below. Upper Limit Related to a, up to 30 bits/word (considered a constraint because of programming inconvenience and inefficiency associated with violating)

		Related to b and c, no real constraint Related to d, constrained by relationship between <u>length</u> of decommutation tables and total demands on both drum storage capacity for permanent storage and core capacity for working area storage Related to e, constrained by relationship between <u>number</u> of decommutation tables per format and total demands on drum storage
B. Number of Formats Which May Be Processed Simultaneously (This is an indication of the number of vehicles whose data may be simultaneously decommutated because, as a function of format design, finite limits exist on the no. of vehicles/format.)	. Up to 2 formats processed simultaneously <u>Limiting factor</u>: 2 operational ground stations at any one time and only 1 format per ground station	<u>Presently Specified Requirement</u> . Up to 4 formats processed simultaneously <u>Upper Limit</u> . Constrained by amount of core memory available for simultaneous storage of different decomm. tables in separate working areas
C. Telemetry Display Driving Capability Independent of RTCC ("Directly driven" terminology does not really apply to CCATS-driven displays when CCATS is viewed as a store-and-forward device)	. 225 events total, selectable for either MOCR/SSR . 100 analogs total, selectable for either MOCR/SSR <u>Limiting factor</u>: Ground station display driving hardware and addressing structure of software instructions	<u>Presently Specified Requirement</u> (or, in this case, any known implementation characteristics) . 125 events via PCM Ground Station and essentially unlimited hardware interface capability for events via Digital Display Drivers (DDD's)

		• 100 analogs total via PCM Ground Station selectable at either MOCR/SSR (Current for AS-204) Upper Limit • Up to 150 analogs via ground station as most significant constraint
D. Number of Missions Capable of Being Simultaneously Supported	• Up to 2 simultaneous missions, 1 operational and 1 simulated Limiting factor: Simultaneous format processing capability assuming 2 formats required per mission	Presently Specified Requirement • Up to 2 simultaneous missions, any combination of simulated and operational Upper Limit • As for command, constrained only by excess computing and storage capacity available

The distinction between the "Presently Specified Requirements" and the "Upper Limit" entries in the CCATS column is considered significant. The former are considered limitations only in the sense that, once these requirements have been implemented in the operational CCATS software package, any significant modification to these may result in a significant software redesign effort. (The obvious importance of careful and farsighted requirements specification is hereby noted.)

The "Upper Limit" entries, on the other hand, are intended to reflect limitations which in a sense are of a more inherent nature than those associated with the implementation of specific quantitative requirements. Once a general software design approach has been defined for accomplishing a particular function, an "Upper Limit" may generally be derived from a knowledge of that aspect of system capacity (computing capacity, storage capacity) upon which the selected approach places the greatest demands. Because they are independent of a quantitative statement of functional requirements, "Upper Limits" as defined herein are themselves not quantifiable in a direct manner; quantification of such constraints must consider the sometimes complex interaction between the various functions which place demands on the same aspect of system capacity. Such constraints are indicated in Table 2-1 because these must be understood in support of any effort to predict the impact of future requirements; i.e., the degree to which these constraints are approached determines the system's capacity for growth.

Discussion of Results

Table 2-1 certainly confirms that certain requirements specified for CCATS in support of Apollo preclude the use of the existing PCM TLM and MDCS Subsystems. CCATS may be generally characterized as having capabilities equal to or greater than those of the existing system for the areas analyzed. It is interesting, as an exception to this general statement, to note that some loss of flexibility in terms of accommodating TLM formats with varying characteristics is apparently associated with the transition to CCATS. This loss of flexibility, however, may most reasonably be interpreted as a reflection of the fact that TLM format characteristics have been better defined for CCATS than evidently was possible for GEMINI at the time of PCM Ground Station specification.

Perusal of the entries in the CCATS column leads, as an expected consequence in the distinction between "Presently Specified Requirements" and "Upper Limits" for this type of system, to the general observation that the utilization of storage and computing capacity are of primary interest relative to the systems ability to accommodate additional requirements.

Conclusions and Recommendations

In addition to the above presentation and discussion of analysis results as significant in their own right, a single general conclusion may be derived from this portion of the analysis. Simply stated, this conclusion is that the transition from the existing TLM and command subsystems (viewed as consisting of special-purpose hardware/software with limited capability by design) to a combination of a general-purpose, relatively large-scale processing configuration and a multi-function software package greatly increases the complexity associated with quantifying, or even understanding, the basic limitations of the system. (This is not to say that this "price" should not be paid.)

Combining the above conclusion with a recognition of the importance of understanding and quantifying system limitations in an environment characterized by continual and somewhat unpredictable requirements changes, the previous recommendation that usage of storage capacity be analyzed is reconfirmed and the additional recommendation that computing capacity usage be analyzed as well is suggested. Because this latter recommendation is developed and discussed in more specific terms elsewhere, no further comment is warranted at this point.

TELEMETRY DATA HANDLING ANALYSIS

Specific Objectives

The Specific Objectives of this portion of the analysis are a further specification of the general objective to analyze significant performance characteristics of the existing system. These are listed in question form:

1. How current is the telemetry data being displayed within the MCCH? (For purposes of this analysis, this question has been addressed in terms of "To what time delays are telemetry parameters subjected during transmission from a vehicle to an MCCH display device?")

2. For parameters whose history as well as the current value is of interest, how well does the trend data displayed represent actual parameter history? (From a display device point of view, this question is associated only with those parameters appearing on a chart recorder display; other display device types - analog meters, event indicators, and TV displays - support only an interest in the current parameter value. Note that these statements intentionally overlook TV trend displays because of the relatively gross time scales involved in displaying TLM trends via this media.)

3. What are the total vehicle-to-display time delays associated with directly driven TLM displays (via the PCM Ground Stations) as compared to computer-driven displays via the RTCC? (For purposes of

this analysis, directly driven displays include analog meters, chart recorders and event indicators in terms of display devices. Computer-driven displays include both event indicators and various types of TV displays where these types are defined generally enough to include, for example, the results of limit sensing by the RTCC regardless of whether a display actually results.)

4. To what extent does the MCCH contribute to the total vehicle-to-display time delay in the cases both of directly driven and computer-driven displays?

5. What is the effect on vehicle-to-display time delays of increasing the vehicle-to-remote site and remote site-to-MCCH sampling rates? (Interest in this question is derived from the observation that, except in the case of parameters associated with trend displays (chart recorders), higher sampling rates external to the MCCH offer operational advantages only in terms of potentially significant time delay reductions. Because the accommodation of higher sampling rates within the MCCH must be equated with some "cost" in terms of using MCCH data handling capacity, the merits of such higher rates are addressed via this question.)

Based on the above, Questions 1 and 2 may be associated with analyzing performance from an operational viewpoint while Questions 3 and 5 may be associated with such analysis from an engineering viewpoint. It is significant to note that the orientation of these two general viewpoints has been satisfied by presenting the same basic data in different forms for interpretation.

Objectives specifically related to CCATS are not considered for this portion of the analysis although the applicability of this and similar analyses to CCATS is commented upon in subsequent paragraphs. Note also that, due to limited MCCH responsibility relative to control and monitoring of the Titan vehicle, only GEMINI and AGENA data has been considered.

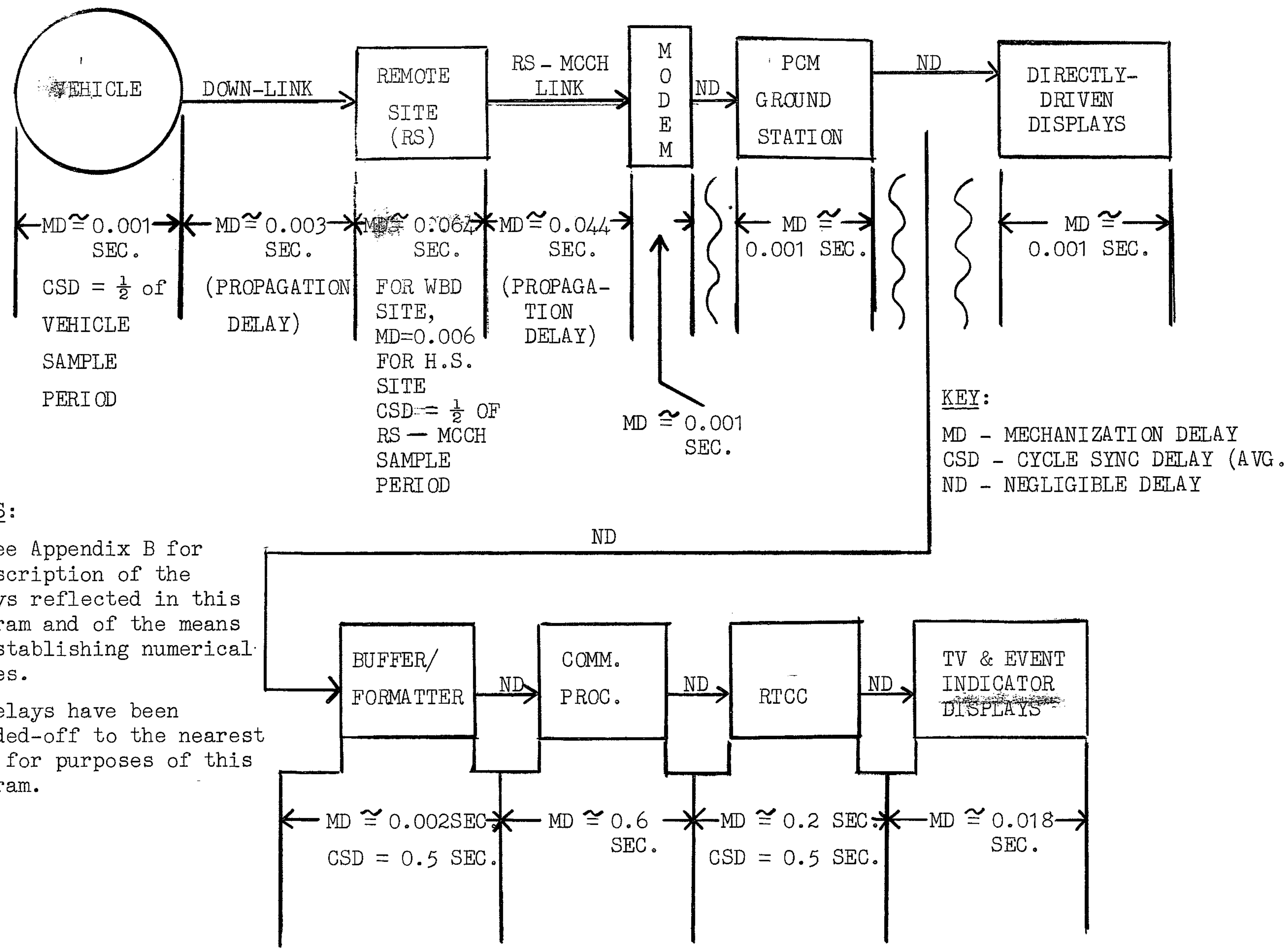
Presentation and Discussion of Results

Sources of Data for Analysis

The specific results presented herein are applicable to the GEMINI VIII mission and have been derived by a parameter-by-parameter study using the GEMINI VIII FCDAR (Revision C) and the GTA-8 Telemetry Data Format Control Handbook as primary data sources. It is emphasized that such an extensive analysis involved GEMINI VIII, not because of a unique interest in this particular mission, but because this mission may be considered representative of GEMINI missions in general. Conclusions and recommendations, therefore, are not identified in the following paragraphs as uniquely associated with GEMINI VIII; these are considered as applicable to GEMINI as a total program unless otherwise noted. Further comments appear below relative to the applicability of detailed quantitative results to other than GEMINI VIII.

Comments on Presentation of Results

Figures 2-1 through 2-7 present the results of this analysis. Basic to the information presented in these figures is the distinction between "Mechanization Delays" and "Cycle Sync Delays" as defined herein.



NOTES:

1. See Appendix B for a description of the delays reflected in this diagram and of the means of establishing numerical values.

2. Delays have been rounded-off to the nearest MSEC for purposes of this diagram.

FIGURE 2-1 TELEMETRY FLOW DIAGRAM INDICATING TIME DELAYS INCURRED

Mechanization delays are associated with the amount of time required by the hardware and/or software comprising each telemetry data handling stage to perform the functions assigned to that stage. In the case of a stage consisting purely of hardware (example, data modem) or consisting of a combination of hardware and software devoted wholely to telemetry functions (example, PCM Ground Station), the mechanization delay is of a relatively fixed nature. In the case of a stage consisting of a hardware/software combination for which telemetry processing is only a portion of an overall task, (example, RTCC) the mechanization delay is of a variable nature dependent on the processing demands associated with other than TLM functions; an average or worst-case delay, however, may generally be estimated.

Cycle sync delays have been distinguished from mechanization delays because, rather than being inherently associated with a particular configuration of data handling hardware/software, these are in a sense "controllable." In particular, cycle sync delays are those which are a direct consequence of the parameter sampling rates specified or of the periodic nature of a TLM processing cycle (examples, Buffer/Formatter and RTCC) characterizing certain TLM data handling stages. Transmission of TLM data between successive data handling stages is of cyclic, repetitive nature. Cycle sync delays exist because the input cycle relative to a given stage is asynchronous with the output cycle from that stage. This means that the time duration between the receipt of a parameter value at the input to a stage and the output of the same parameter from that stage is not fixed. In the worst case, this duration will be equal to the output cycle period (a processing cycle in some cases, a commutation cycle whose period is determined on a parameter-by-parameter basis by the desired sampling rate in other cases). On the average, this duration will be equal to one-half of the output cycle period. These durations are defined herein as Cycle Sync Delays with average values being employed unless otherwise noted. Returning to the idea that cycle sync delays are in a sense "controllable", the implication of this discussion is that these are determined directly by per parameter sample rate specifications or by the specification of fixed period processing cycles within a device. It is recognized, of course, that the practical degree to which such delays are "controllable" is limited by many factors external to the MCCH including TLM format design constraints and the characteristics of the on-board TLM communication system.

Concerning the specific quantification of both mechanization and Cycle Sync Delays, each delay type (when applicable) is presented for each TLM data handling stage in Figure 2-1. Appendix B may be consulted for a description of the assumptions, calculations, etc., associated with the derivation of the values continued in Figure 2-1.

No conceptual complexity is required to consider the degree to which chart recorder displays represent actual parameter history. This issue may be considered directly in terms of the remote site-to-MCCH sampling rate when viewed as the "data update" rate into the PCM Ground which, in turn, is preserved by the ground station for direct output to a chart recorder.

Any further comments required to clarify the data presentation are included within the following discussion of results.

Discussion and Summarization of Results

1. How current is the telemetry data being displayed within the MCCH?

Figures 2-2, 2-3, and 2-4 present the analysis results relative to this objective. Both total delays and their cycle sync components are indicated for each vehicle sampling rate. The indication of the cycle sync component being included to graphically

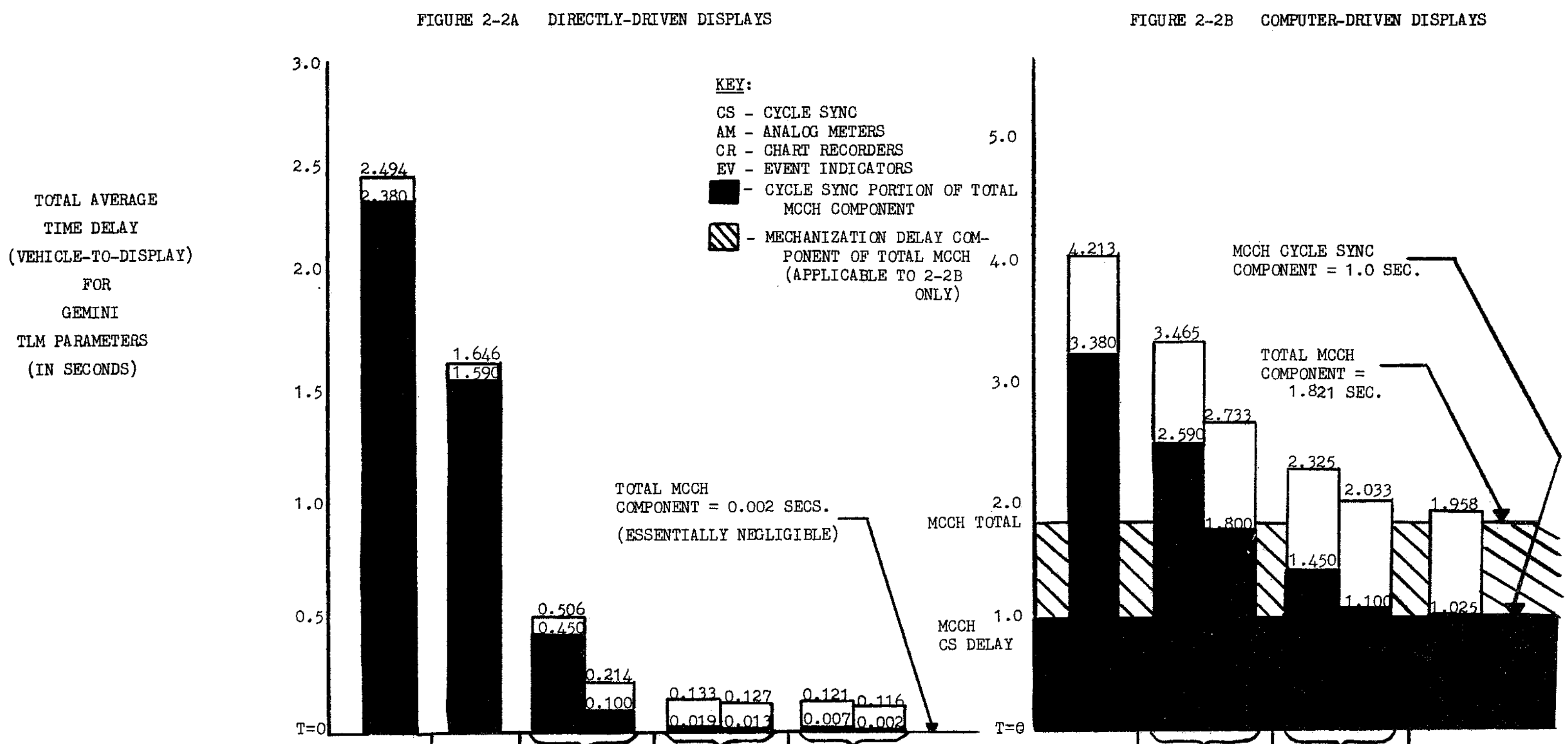


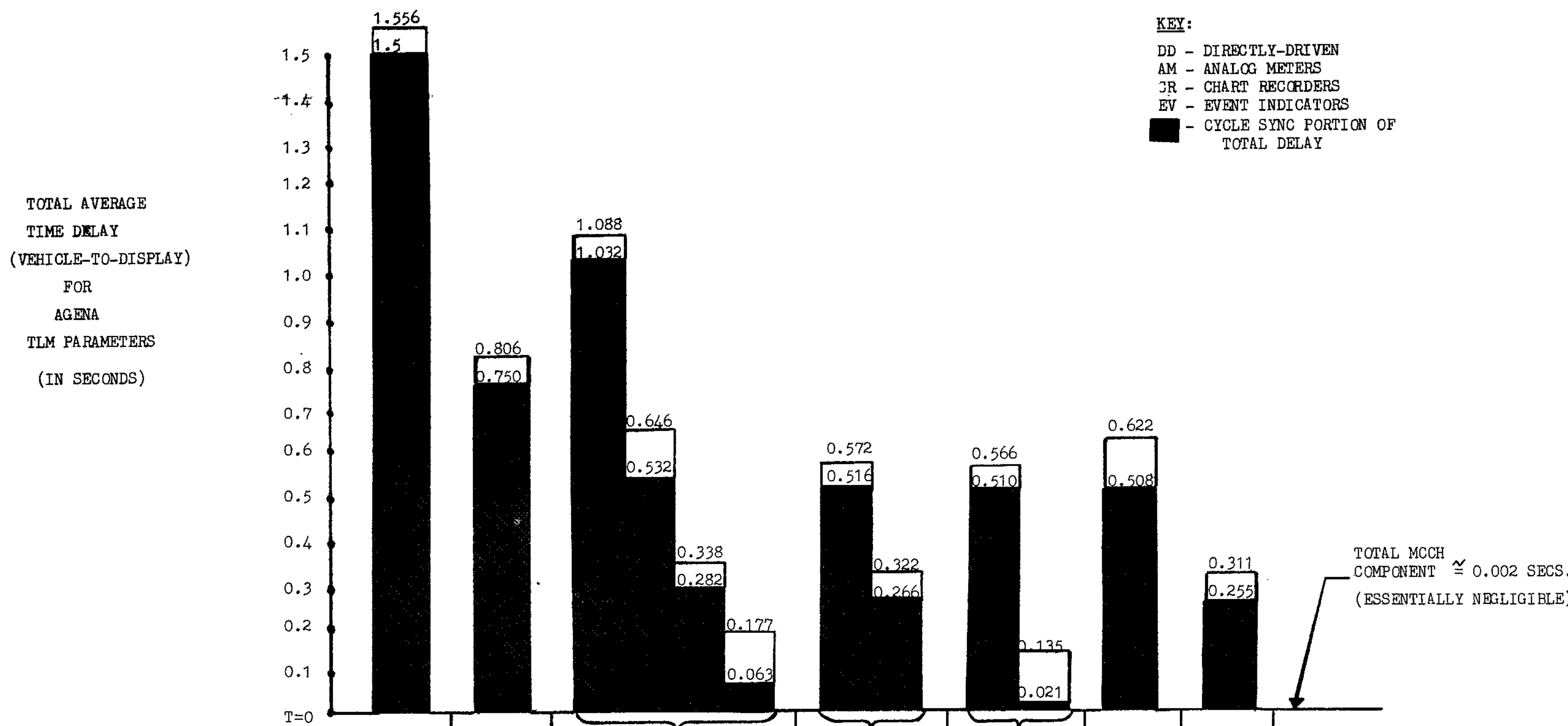
Figure 2-2A — Directly-driven displays

VEHICLE SAMPLE RATE (SAMPLES/SEC) :	0.42SPS	1.2SPS	10 SPS		80 SPS		640 SPS	
SAMPLE PERIOD (SECS/SAMPLE) :	(2.380)	(0.8)	(0.1)		(0.013)		(0.002)	
# PARAMETERS AT THIS RATE (APPLIC. TO GTA-8) :	6	27	63		3		6	
FOR EACH TIME DELAY GROUPING IN FIGURE 2A -								
#PARAM. ON AM & CR DISPLAYS :	3	17	-	-	-	-	-	-
#PARAM. ON AM DISPLAY ONLY :	3	6	-	-	-	-	-	-
#PARAM. ON CR DISPLAY ONLY :	-	3	7	1	2	-	2	4
#PARAM. ON EV DISPLAY :	-	1	55	-	-	1	-	-
TOTAL # PARAM. IN GROUPING :	6	27	62	1	2	1	2	4

Figure 2-2B — Computer-driven displays

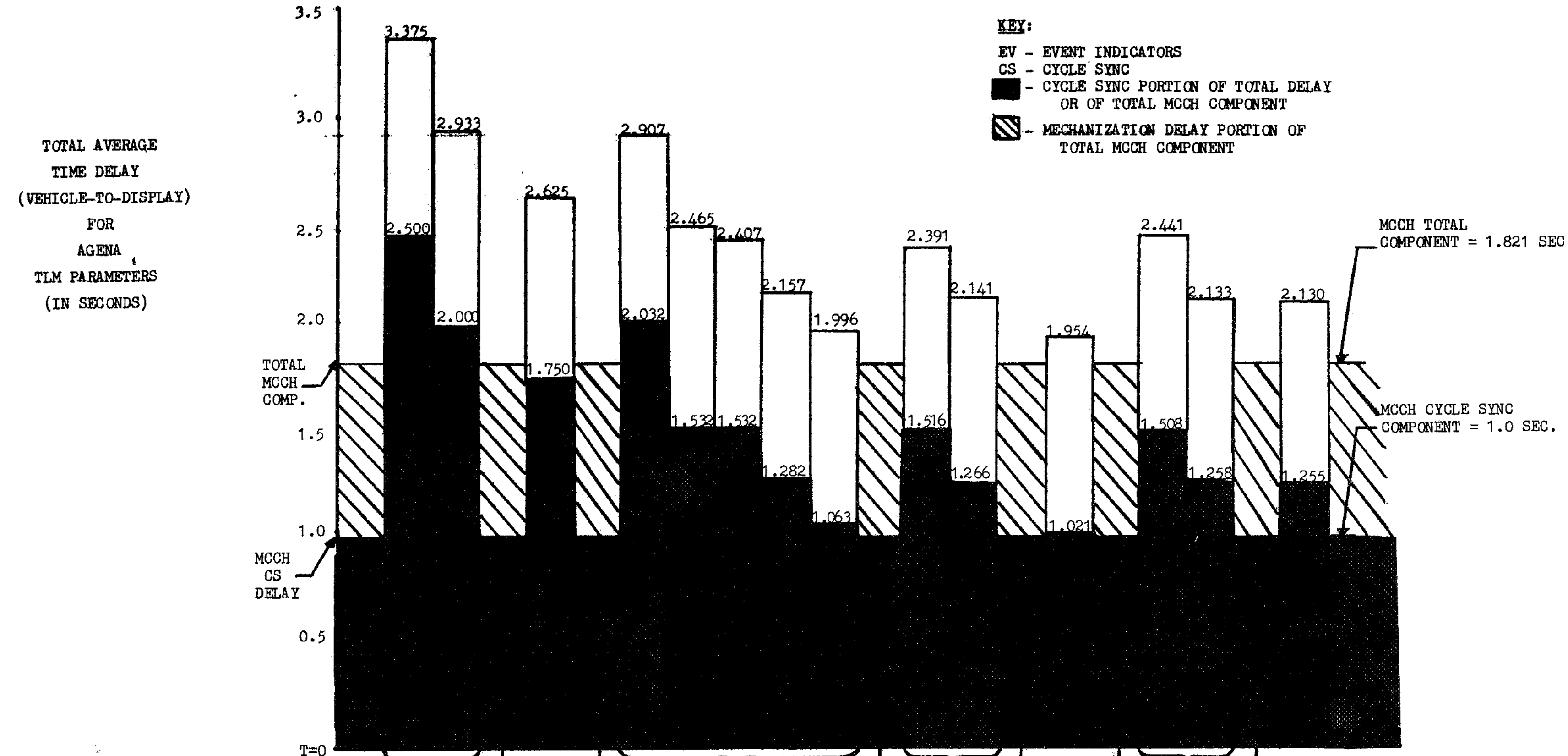
VEHICLE SAMPLE RATE	0.42SPS	1.2 SPS		10 SPS		40 SPS
SAMPLE PERIOD	(2.380)	(0.8)		(0.1)		(0.025)
# PARAMETERS AT THIS RATE	38	79		75		3
FOR FIGURE 2B GROUPINGS -						
#PARAM. ON EV DISPLAY :	-	-	-	46	-	-
#PARAM. ON TV-DISPLAY :	38	73	6	28	1	3
TOTAL # PARAM.:	38	73	6	74	1	3

FIGURE 2-2 TIME DELAYS ASSOCIATED WITH BOTH DIRECTLY-DRIVEN & COMPUTER-DRIVEN DISPLAYS OF GEMINI TELEMETRY PARAMETERS



VEHICLE SAMPLE RATE (SAMPLES/SEC) :	1 SPS	2 SPS	16 SPS				32 SPS		48 SPS		64 SPS	96 SPS	
SAMPLE PERIOD (SECS/SAMPLE) :	(1)	(0.5)	(0.063)				(0.032)		(0.021)		(0.016)	(0.010)	
# PARAMETERS AT THIS RATE (APPLIC. TO GTA-8 FOR DD DISPLAYS) :	2	1	18				4		5		1	1	
FOR EACH TIME DELAY GROUPING -													TOTALS
# PARAM. ON AM & CR DISPLAYS :	-	-	2	-	10	-	-	-	-	-	-	-	13
# PARAM. ON AM DISPLAY ONLY :	-	-	2	-	-	-	-	-	-	-	-	-	2
# PARAM. ON CR DISPLAY ONLY :	2	1	1	1	-	2	2	2	3	1	1	-	16
# PARAM. ON EV DISPLAY :	-	-	-	-	-	-	-	-	-	1	-	-	1
TOTAL # PARAM. IN GROUPING :	2	1	5	1	10	2	2	2	3	2	1	1	32

FIGURE 2-3 TIME DELAYS ASSOCIATED WITH DIRECTLY-DRIVEN DISPLAYS OF AGENA TELEMETRY PARAMETERS



VEHICLE SAMPLE RATE (SAMPLES/SEC) :	1 SPS		2 SPS	16 SPS					32 SPS		48 SPS	64 SPS		96 SFS	
SAMPLE PERIOD (SECS/SAMPLE) :	(1.0)		(0.5)	(0.063)					(0.32)		(0.021)	(0.016)		(0.010)	
# PARAMETERS AT THIS RATE (APPLIC. TO GTA-8 FOR CD DISPLAY) :	90		1	36					16		1	4		1	
FOR EACH TIME DELAY GROUPING -															TOTALS
# PARAM. ON EV DISPLAY :	2	5	-	-	-	-	3	-	-	-	1	-	-	1	12
# PARAM. ON TV DISPLAY :	72	11	1	11	1	8	10	3	4	12	-	3	1	-	137
TOTAL # PARAM. IN GROUPING :	74	16	1	11	1	8	13	3	4	12	1	3	1	1	149

FIGURE 2-4 TIME DELAYS ASSOCIATED WITH COMPUTER-DRIVEN DISPLAYS OF AGENA TELEMETRY PARAMETERS

illustrate the significance of this component relative to total delays. Although the total delay associated with a given parameter may be dependent upon the type of site - high-speed or wide-band - processing the data at any given time, it was determined that the worst-case delay for each type of site must be considered most meaningful from an operational viewpoint. As a result, the worst-case remote site delay for each parameter is reflected in all of the three figures. (Not to be confused with the worst-case delay achieved by using the maximum other than the average cycle sync delay.) Note that the worst-case site delay is generally associated with the high-speed sites as a consequence of lesser remote site-to-MCCH sampling rates; exceptions occur when sampling rates are high enough that cycle sync delay differences are outweighed by the greater mechanization delay associated with Cape Kennedy data.

The technique of presenting total delays on a per vehicle sampling rate basis rather than presenting a distribution of delays over all parameters independent of their vehicle rates has been selected on the following basis: the vehicle sampling period is a reflection of a decision (perhaps not explicit) concerning the criticality of each parameter from a time delay point of view. A lower limit is placed on the average time delay for a parameter once a vehicle sampling rate is established (and again when the remote-site-to-MCCH rate is specified). A comparison of the total delay with the vehicle sample period, therefore, is considered useful from an operational viewpoint. The parameter totals and subtotals for each type of display device have been provided to permit any operational value judgments generated by NASA to "weight" the various bars on a quantitative basis.

Relative to the applicability of the GEMINI VIII data in Figures 2-2 through 2-4 to GEMINI missions in general, it might be commented that only the cycle sync portion of the total delay may be considered as a mission variable. This is determined by the combinations of vehicle and remote site-to-MCCH (known as G/G or ground-to-ground rate from this point on) sampling rates selected. In practice, however, these combinations are relatively constant for all missions. In addition, the number of parameters associated with each time delay and, in turn, with each vehicle and G/G sample rate combination is also a mission variable. In this case, the variation is real, but would not be expected to be of such a magnitude to significantly alter the relative weighing of different time delay results.

The above discussion is insensitive to the distinction between computer-driven and directly driven displays. Considering this distinction and recognizing the validity of expressing ranges of total delays rather than somewhat artificial across-the-board averages, pertinent figures may be compiled as follows:

For GEMINI:

Range of delays for directly driven displays	0.116-2.494 seconds
Range of delays for computer-driven displays	1.958-4.213 seconds

For AGENA:

Range of delays for directly driven displays	0.135-1.556 seconds
Range of delays for computer-driven displays	1.954-3.375 seconds

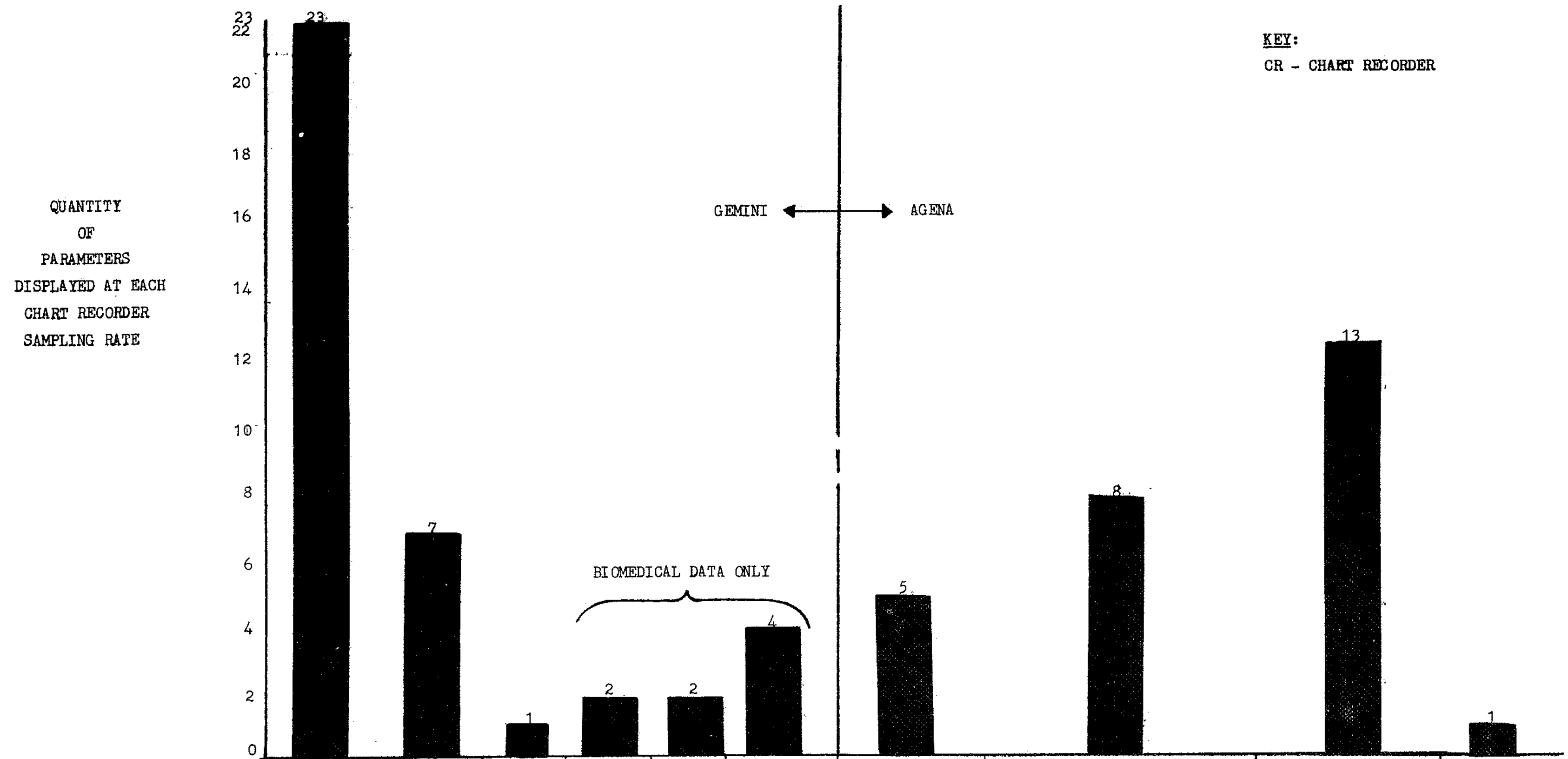
Note that for values at the extreme upper end of each of these ranges, the cycle sync component constitutes between approximately 74 and 97 percent of the total time delay, an indication of the relatively large cycle sync components at the lower range of sampling rates. The relationship between sampling rates and total delays may be crudely assessed by viewing the general pattern of reduction in total delays as the vehicle sample rate increases. Exceptions to this pattern exist because an increase in the vehicle sampling rate may or may not be associated with an increase in the G/G rate.

Because the objective of describing the time delays associated with TLM display data is considered to be satisfied primarily by Figures 2-2 through 2-4, quantitative manipulation or summarization of data other than presented above is not included in this report; other interpretations of the results in support of specific interests should be easily derivable once the data is understood.

2. <u>How well does the trend data displayed (on chart recorders) represent actual parameter history</u>?

Figure 2-5 consists of a straightforward tabulation of the number of parameters "updated" on chart recorder displays at each of several rates. Parameter quantities again permit "weighting" of the operational significance of the data presented. It is interesting to note that chart recorder data, rather than being associated primarily with high sample rate data, involves a wide range of sample rates with the greatest number of parameters updated at low sample rates.

The more detailed supporting information provided in Figure 2-5 under the heading, "For Each CR Sample Rate" is of secondary importance, this data is not required to support the primary objective of this chart. Such data is provided, however, to indicate types of questions related to telemetry data handling which might be of legitimate interest in a more comprehensive analysis. By observing the



CR DATA SAMPLE RATE (WHEN BEING RECEIVED FROM HIGH-SPEED SITE) :	0.42SPS		1.2SPS	10SPS	40SPS*	80SPS*	320SPS*	0.5SPS		1SPS					2SPS			48SPS
FOR EACH CR SAMPLE RATE - DIFFERENT VEHICLE RATES	0.42	1.2	10	10	80	640	640	1	16	2	16	32	48	64	16	32	96	48
QTY. AT EACH DIFFERENT RATE:	3	20	7	1	2	2	4	2	3	1	1	2	3	1	10	2	1	1
CR SAMPLE RATE WHEN RECEIVED VIA WBD DATA :	0.42	1.2	10	10	40	80	320	1	16	2	1	16	48	1	16	16	48	48

* Received via FM/FM from H.S. Sites via WBD from Cape until GTA-9; then via FM/FM

FIGURE 2-5 EFFECTIVE CHART RECORDER SAMPLING RATES AND ASSOCIATED QTY. OF GEMINI AND AGENA PARAMETERS different vehicle rates associated with the same chart recorder sample rate, for instance, the question is raised of the need for these various combinations (five different AGENA vehicle rates result in the same chart recorder sample rate of 1 SPS) in cases where the different vehicle rates may not be interpreted as clearly associated with different time delay requirements (the only valid operational reason for requiring different vehicle rates). As another example, a comparison of the CR (chart recorder) sample rates associated with receipt from a high-speed site with the rates for the same parameters when being received from Cape Kennedy indicates that only seven of fifty-eight non-biomedical parameters are "updated" on a chart recorder display at the same rate regardless of the site source: why require a higher sampling rate from Cape Kennedy? It is recognized that the answers to such questions may lie in a full understanding (not possessed by this author) of the G/G format design constraints, the nature of the on-board commutation hardware, etc. The existence of such potentially useful areas of investigation is considered, however, to be worthy of note as a byproduct of this analysis.

3. What are the comparative time delays associated with directly driven vs. computer-driven displays?

Addressing this question involves only a straightforward comparison of Figure 2-2A with 2-2B or Figure 2-3 with 2-4 depending upon the vehicle of interest. It must be cautioned, however, that specific quantitative comparisons are meaningful only when involving delays for directly driven and computer-driven displays which include the same external cycle sync delay component. This component, a direct function of the combination of vehicle and G/G sample rates, must be maintained constant for both "sides" of each individual comparison to produce a result which includes only those time delay differences uniquely associated with the difference between the computer-driven and directly driven display processing stages internal to the MCCH.

The process of determining those total delays permitting legitimate comparison by virtue of identical external cycle sync components is, of course, not required if interest is only in the absolute value of the differential. This is a constant of 1.819 seconds which is simply the difference between the total MCCH time delay component (1.821 seconds) for computer driven displays and the total MCCH time delay component for directly driven displays (0.002 seconds). For a few representative combinations of vehicle and G/G data sampling rates, expressing this differential as a percentage of the total time delay for computer driven displays gives the following results:

For GEMINI

Vehicle SPS	G/G SPS	Percent of Total Delay
0.42	0.42	42
1.2	1.2	52
10	1.2	78
10	10	90

For AGENA

Vehicle SPS	G/G SPS	Percent of Total Delay
1	0.5	54
2	1.0	69
16	0.5	63
32	1.0	76
48	48.0	93
96	2.0	86

The vehicle and G/G sampling rate combination of 0.42/0.42 SPS for GEMINI results in the maximum value for cycle sync time delays external to the MCCH. This case, therefor, minimizes the percentage differential of time delays along the two display paths of interest. The minimum differential is 42% of the total computer driven time delay for the data sample rates currently used in GEMINI missions.

4. <u>To what extend does the MCCH contribute to the total vehicle-to-display time delays in the cases of both directly driven and computer-driven displays</u>?

Figures 2-2 through 2-5 must again be consulted. In this case, however, the pertinent feature of these figures is the indication of the time delay components attributable to the MCCH. In the case of directly driven displays, the answer to the question of interest is as stated on the figures themselves: the MCCH component of the total delays is essentially negligible. Such a result is as would be expected based on an understanding of the MCCH data handling devices involved in processing TLM data for directly driven display use.

The case of the MCCH contribution to total delays for computer-driven displays is far different, but again is what would be expected as a function of the MCCH data handling stages involved. Figures 2-2B and 2-4 illustrate graphically that the total MCCH delay component in this case comprises a lower limit of 1.821 seconds (noted above in a different context). Without belaboring the manipulation of numbers involved, two significant cases may be identified as follows:

The MCCH component of total delays related to computer-driven displays constitutes -

For GEMINI, a minimum of 42.2% of the total delay
For AGENA, a minimum of 54.0% of the total delay
(minimum percentage = percentage of greatest total delay indicated)

Note that Figure 2-2B and 2-4 indicate the 1.0 second cycle sync component of the total MCCH delay as well as the MCCH total itself. If one were to conclude that a reduction of the total MCCH delay was required to satisfy operational requirements, this further breakdown of the total delay would be of interest to indicate the potentially most fruitful areas for achieving reduction. In this case, the MD and CS delay components are nearly equal and a further breakdown is required as follows based on Figure 2-1.

MCCH Stage	Mechanization Delay	Cycle Sync Delay	Total Stage Delay
Buffer/Formatter	0.002 sec.	0.500 sec.	0.502 sec.
Comm. Processor	0.600	--	0.600
RTCC	0.200	0.500	0.700
Display Hardware	0.018	--	0.018
MD Subtotal	0.820	CS Subtotal 1.000	TOTAL 1.820*

*Unequal to 1.821 due only to rounding prior to totaling in this case.

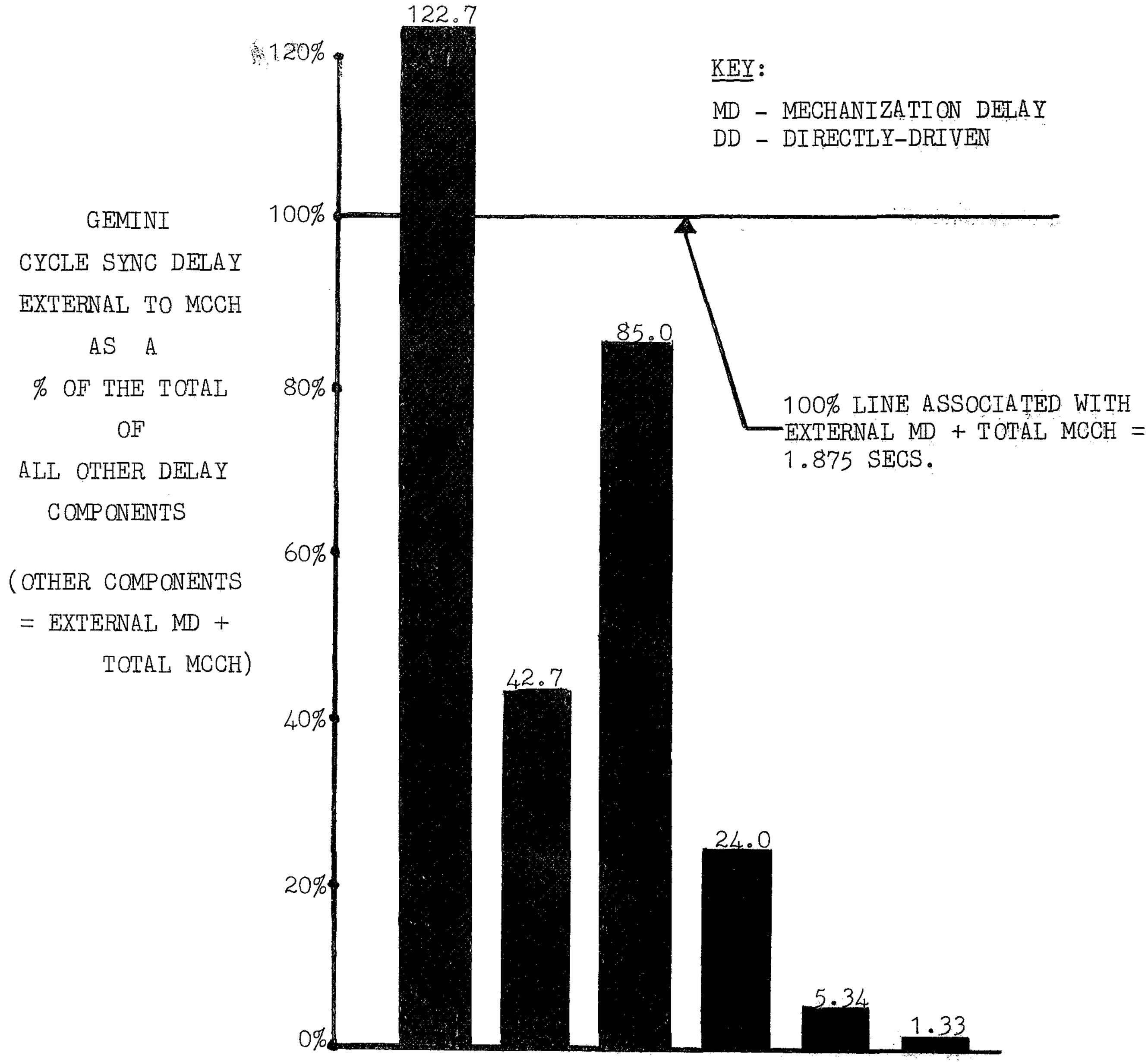
Implications of this breakdown are that particular areas might be considered first in achieving the delay reduction goal hypothesized above: Communication Processor, Mechanization Delays, B/F and RTCC cycle sync delays. This discussion, because of the hypothetical nature of the goal assumed and the inapplicability of the numbers shown to CCATS and the 360/75 environment, is illustrative only of the importance of understanding the breakdown of a total time delay in terms of the relative significance of its components.

5. <u>What is the effect on vehicle-to-display time delays of increasing the vehicle-to-remote site and remote site-to-MCCH sampling rates?</u>

The qualitative answer to this question is known based on the previous discussion of cycle sync delays; total delays decrease as sampling rates increase. Because time delay reductions are desirable from an operational viewpoint, one might dismiss any further consideration of the question with the statement that sampling rates should always be maximized. Such a statement, however, ignores the costs in terms of MCCH system processing capacity incurred by handling TLM data at successively higher sampling rates. Because the trade-offs between processing costs and time delay reductions must be determined in support of sound design decisions, this study addressed that portion of such a trade-off analysis concerned with time delays. The intent is primarily to investigate and illustrate an appropriate analytic technique.

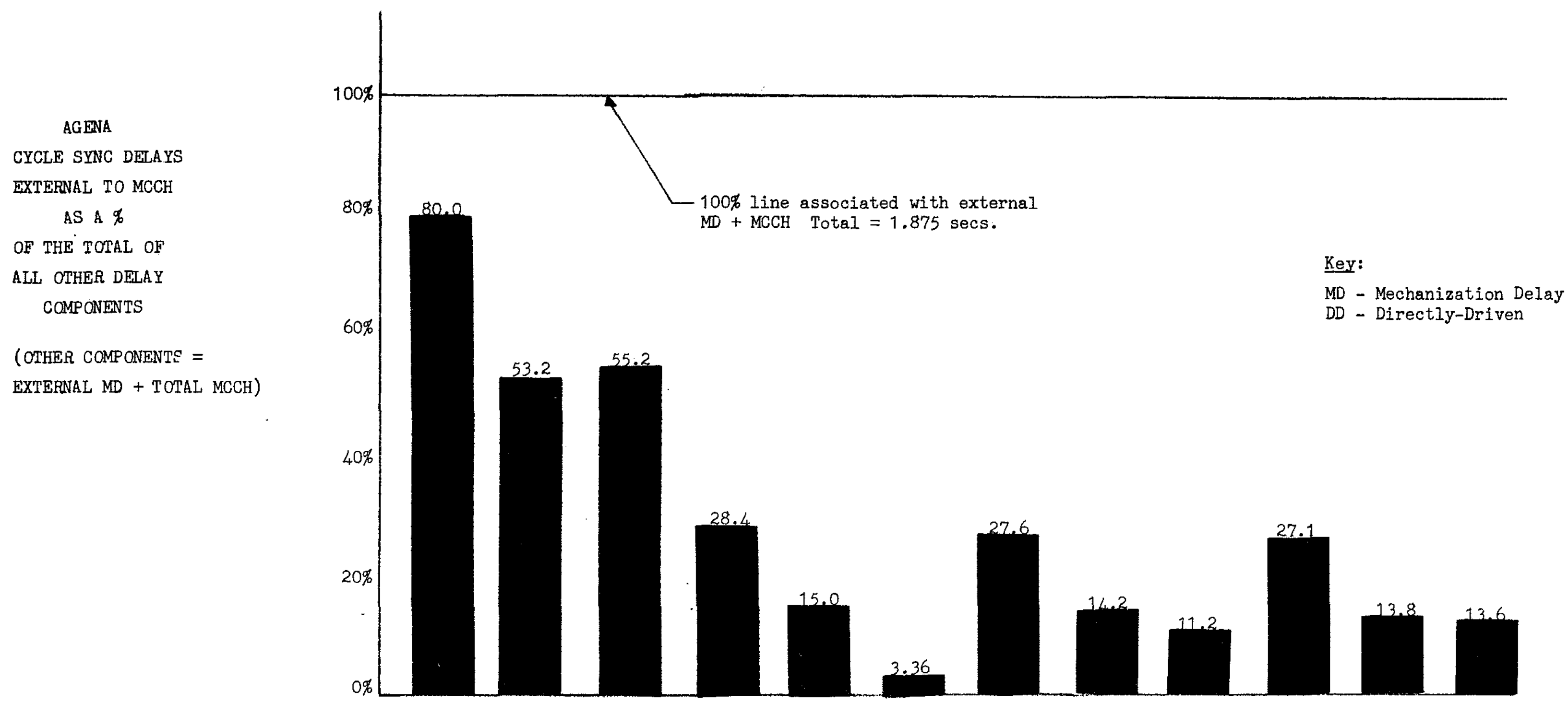
The effect on time delay reductions has been examined by expressing the cycle sync delays incurred external to the MCCH (these components may be equated to the consequence of selecting vehicle-to-remote site and G/G sample rate combinations) as a percentage of all other time delay components. The results, then, quantify the extent to which sampling rates contribute to total data delays. Figures 2-6 and 2-7 present these results. Results for parameters appearing <u>only</u> on directly driven displays are not included; external cycle sync delays for such cases will always appear significant when compared to other delay components, as a consequence of the small MCCH mechanization delays. In addition, parameters which appear on computer-driven displays <u>but also</u> on chart recorder displays are not reflected in the results; in these cases the display update rate (equal to G/G sample rate) as well as total time delays must be considered to assess operational significance. Specifically, results show a range of 1.33% to 122.7% describes the contribution of external cycle sync delays to total time delays.

Although no quantitative criterion is known to this author for determining operational significance, a criterion may be assumed



VEHICLE SAMPLE RATE	:	0.42SPS	1.2	1.2	10	10	40
REMOTE SITE ⟶ MCCH SAMPLE RATE	:	0.42	1.2	0.42	1.2	10	40
APPLICABLE SITE TYPE (For worst total delay)	:	WBD	WBD	H.S.	H.S.	WBD	WBD
TOTAL PARAMETER QTY.	:	35	6	54	74	1	3
QTY. <u>NOT</u> ASSOCIATED WITH DD DISPLAY	:	33	6	44	40	1	3

FIGURE 2-6 FOR GEMINI PARAMETERS APPLICABLE TO COMPUTER-DRIVEN DISPLAYS, EXTERNAL CYCLE SYNC DELAYS AS A % OF ALL OTHER DELAYS



VEHICLE SAMPLE RATE	:	1.0SPS	1.0	16	16	16	16	32	32	48	64	64	96
REMOTE SITE→MCCH SAMPLE RATE	:	0.5SPS	1.0	0.5	1	2	16	1	2	48	1	2	2
APPLICABLE SITE TYPE (For worst-case total delay)	:	H.S.	WBD	H.S.	H.S.	H.S.	WBD	H.S.	H.S.	WBD	H.S.	H.S.	H.S.
TOTAL PARAMETER QTY.	:	72	16	8	8	5	3	2	10	1	2	1	1
QTY. <u>NOT</u> ASSOCIATED WITH DD DISPLAYS	:	72	16	6	8	5	1	2	10	--	2	1	1

FIGURE 2-7 FOR AGENA PARAMETERS APPLICABLE TO COMPUTER-DRIVEN DISPLAYS, EXTERNAL CYCLE SYNC DELAYS AS A % OF ALL OTHER DELAYS

for describing the application of results such as those presented. Assume for discussion that any contribution of less than 10% is considered insignificant. Applying this criterion to Figures 2-6 and 2-7 leads to the observation that a total of four GEMINI parameters and three AGENA parameters are handled at sample rate combinations which contribute an insignificant delay component to the total delay for these parameters. In these cases, consideration should be given to handling these parameters at lower sample rate combinations as long as the clip-level of 10% is not exceeded. This type of application of the techniques described involves a parameter-by-parameter study of previously specified sample rates.

A more important application is the formulation of a design ground rule for the specification of sampling rate combinations. This may be accomplished by calculating some percentage (e.g. 10%) of the value of the sum of all delays other than sampling rate delays assuming the worst-case version of these (10% of 1.875 for the results presented). The result of this calculation - 0.188 seconds - may be used as follows: no parameters shall be sampled at down-link or G/G combinations which result in an external cycle sync delay of less than 0.188 seconds unless for reasons other than support of operational time delay requirements. In summary, this technique allows one to relate the effect of sampling rate time delays to other design considerations.

Conclusions and Recommendations

Conclusions stated below do not include those requiring operational value judgments of the adequacy of time delays or sample rates associated with TLM displays. It is intended that the presentation and discussion of results will support any such judgments to be made by NASA personnel. Certain of the conclusions stated actually consist of a summary of significant results. Conclusions are as follows:

- Total average time delays for all directly driven display data fall within a range of 0.1 to 2.5 seconds.

- Total average time delays for all computer-driven display data fall within a range of 2.0 to 4.2 seconds.

- Delay components resulting from vehicle and remote site-to-MCCH sampling rate specifications generally constitute a significant portion of the total vehicle-to-display time delay.

- A significant reduction in total time delay to a display is achieved by employing directly driven displays (via ground station) rather than computer-driven displays (via RTCC): absolute reduction (avg.) of 1.8 seconds. Minimum percentage reduction of 42%.

- The MCCH component of the total time delays in the case of directly driven displays is essentially negligible.

- The MCCH component of the total time delays in the case of computer-driven displays is significant:
  - absolute value of 1.8 seconds (avg.).
  - minimum of 42% of total delay

- The analytic techniques employed to satisfy the specific objectives identified for this analysis are generally applicable to addressing the same issues for different system configurations.

- The analytic technique employed herein may be viewed as appropriate to address a variety of issues different than but related to those specifically addressed.

Although several of the quantitative conclusions stated above are certainly not surprising, their quantification is intended to support the establishment of a baseline of MCCH performance. Assuming this baseline to be sufficient as related to the existing TLM subsystem while recognizing areas not specifically addressed, it appears reasonable to consider the usefulness of such an analysis or version thereof for expected CCATS performance. Because this author's knowledge of CCATS is insufficient to permit a detailed assessment of which questions are of interest, only a general recommendation is made as follows:

> It is recommended that CCATS issues of significant interest which may be addressed using the techniques employed herein be identified and evaluated for possible pursuit as an extension of this analysis.

COMMUNICATIONS PROCESSOR LOADING ANALYSIS

The term "loading" as used herein refers to the usage of computing capacity and is expressed as the percentage of time (during the interval selected for collecting analysis results) occupied with the performance of data handling functions. The term "communications processor" is used in a general sense to include both the combination of Univac 490 hardware with the present GEMINI software package and the yet to be realized CCATS combination of Univac 494 hardware with a new Apollo-oriented software package. These two hardware/software combinations are distinguished as required within this report by specifically referring to either the existing system or CCATS.

Specific Objectives

The objectives of this portion of the analysis reflect two important constraints. Because no technique for assessing communications processor loading had been implemented within the existing system, this analysis by necessity included assisting in the development of such a technique. Objectives stated below reflect the fact that this effort is not yet considered complete. Because the CCATS configuration is not yet in a state permitting empirical analysis, objectives related to the quantification of CCATS loading are severely limited.

Specific Objectives are as follows:

1. Achieve two specific loading measurements associated with the support of a peak operational GEMINI traffic situation -

   For the Univac 490 as a basic system capacity figure quantifying loading on the existing system in response to a peak load.

   For the Univac 494 as an indication of the percentage of CCATS 494 capacity required to support the GEMINI portion of a CCATS simultaneous mission configuration involving GEMINI as one of the two missions.

2. For the loading measurement technique employed (described below), assess its ability to provide meaningful results in terms of an overall figure for system loading. ("Overall" as opposed to a breakdown which indicates which portion of the overall loading is associated with which software functions.)

3. Investigate the usefulness of this same measurement technique to achieve a useful picture of the relationship between overall system loading and the various functional components of this loading. (This "picture" constitutes a particular form of loading breakdown as is discussed in subsequent paragraphs.)

4. Derive a numerical ratio which expresses the approximate degree of computing capacity increase associated with making the transition from a 490 to a 494 processor. Although this objective is considered secondary, such a ratio is hopefully useful in support of a more quantitative understanding of the actual advantages associated with the 494 augmentation.

Objectives "1" and "2" are obviously closely interrelated, the same technique used to achieve measurements is simultaneously being assessed for validity. Analysis results, relative to those two objectives, are, therefore, discussed together.

To provide a better understanding of why one would be interested in obtaining overall system loading figures and some form of a breakdown thereof, it is useful to consider the questions which such figures might answer. There are two basic questions of interest:

> From an interest in the present operating margin, "What portion of the total capacity am I presently using?"
>
> From an interest in the impact on the present operating margin of new demands on the system, "What portion of the total capacity will I be using once these new demands have been accommodated?"

The first question is an important one which may be answered using any technique which provides a measure of overall loading; thus the associated objective above. The second question, on the other hand, may be answered <u>only</u> if the ability exists to <u>predict</u> the incremental impact on the overall loading of any new demand stated in terms of more data (in a general sense) or new functions. In other words, the second question requires the ability to view loading for each type of data or function despite the fact that the end result is stated in overall loading terms.

A basic premise concerning the particular operational traffic situation for which answers to the above questions should be derived is as follows: the highest conceivable level of operational traffic is the situation of most interest because the system must be designed at least to handle this situation. Note that this situation is not synonymous with a theoretical peak defined as the simultaneous receipt of input data from all possible data sources at their maximum data rates; such a peak is not of practical interest from an overall loading viewpoint.

Presentation and Discussion of Results

1. Data Collection

A simple addition to the present communications processing software package provided the basic tool for collection of appropriate empirical or usage data. Once the nature of the NASA and MITRE interests in data collection were specifically defined, this addition was designed and implemented expeditiously by Univac personnel. Technically, the nature of this change may be briefly explained as follows:

That portion of the communications processing software system which schedules other portions of the software system to operate in response to input data is known as "Switcher." Switcher may be viewed as a scanner which starts at the top or high priority end of a register containing indicators of tasks to be performed and proceeds toward the low priority end. If no tasks require scheduling, Switcher exits from the low priority end of the "job register" and immediately starts again at the top. If there are tasks to be performed, Switcher stops scanning, schedules the appropriate portion of the software package to operate and waits until the task has been completed. Once a task has been completed, Switcher again begins its cyclic scanning sequence starting at the top of the "job register."

The data collection tool added to the software takes advantage of the Switcher characteristics described above. Specifically, the program addition permits the recording on magnetic tape of the number of times (within one of several selectable intervals) the Switcher program exits from the low priority end of the "job register." Each recorded count is accompanied by an appropriate time tag and because each cycle of Switcher requires a fixed and predictable amount of time, permits a direct calculation of the amount of time within the recording interval that no processing tasks were required. This then is the percentage of computing capacity not used and may be easily converted to a loading figure.

The program change described above is considered generally suitable for long-term use. Certain details of the present implementation, however, would require minor modification to simplify the mechanics of data reduction in support of extensive and continuing future use.

Using the Switcher cycle count technique described, usage data was collected for each of thirteen different pre-defined measurement configurations distinguished from one another by the specific complement of data inputs involved. One of the thirteen configurations consisted of all those inputs required to support loading measurements for peak operational traffic conditions. All other loads were designed to support investigation of the applicability of the Switcher cycle count technique to support a determination of various loading components as per objective "3". To the extent required to permit an understanding of the results reported, measurement configurations are defined below.

Other significant conditions relative to data collection are:

. Measurements for all configurations were taken while running both the 490 and 494 in parallel using the dynamic standby concept operationally employed in the MCCH. (The program change, of course, was added to both the 490 and 494 versions of the software system tape.) This permitted the convenient collection of comparative data on both machines.

. Data was recorded for all configurations using a 1 second interval; i.e., the count of Switcher cycles was recorded and then reset once per second.

. The total time periods over which data was recorded for each configuration were either 1, 2, or approximately 5 minutes depending upon the particular configuration. Total periods of data collection were defined specifically for each configuration as adequate to permit any repetitive patterns to be observed or random peaks to be experienced. More detailed test information is presented in Appendix B.

A final comment is appropriate regarding the means of converting the count information recorded to loading measurements. Switcher count data was recorded for a 2 minute period with no data being input to the processors (a fourteenth configuration). This particular count data, then, was used to calibrate all other measurements by considering the maximum number of cycles within any given second during the "no data" period to correspond to a zero percent loading situation. This data indicated that, with no tasks to be scheduled, the following number of Switcher cycles occur per second: 46,400 for the 494; 5,973 for the 490.

2. Peak Loading Results and Implications

In agreement with NASA personnel and in accordance with definitions previously derived in support of the series of Bellcomm theoretical studies, the peak operational traffic situation was based on a GEMINI launch coincident with an AGENA flyby at Cape Kennedy. As a result, the input traffic associated with this configuration involved all of the following sources: all DCU-R units devoted to the reception of GE/B and IP data from Cape Kennedy and of Bermuda radar data, the Buffer/Formatter, a selected number of teletype devices, an MDCS unit (simultaneous command transmission assumed), and the RTCC (TLM Rebroadcasts and command loads). A specific description of this configuration is contained in Appendix B. Data was taken at 1 second intervals for approximately 5 minutes. Averaging the data recorded during this 5 minute period and converting to a percentage of computing capacity used figure, the following results were obtained:

For 490, operating at 68.0% during the peak traffic situation

For 494, operating at 13.3% during the same peak traffic situation

Appendix B may be consulted for a description of the data averaging technique employed and any assumptions made in achieving these results.

The 490 result of 68% is particularly interesting viewed as an indication of the ability of this machine to accomplish the CCATS task. Although any detailed statements regarding the influence of new CCATS software functions, network changes, etc., can not be made at this point, it appears reasonable to make the assumption that support of a single Apollo mission will require at least as much computing capacity as a single GEMINI mission. Making this assumption leads to doubling of the 68.0% result to predict CCATS loading for two simultaneous missions. Noting that a peak demand for greater than 100% of computing capacity will be met by using 100% of capacity until the machine can "catch up" leads to the conclusion that, as the minimum operational cost, abnormal delays will be incurred. Noting further that such a demand could conceivably continue for the duration of at least a single over-station pass period, data loss becomes a serious concern although not a surety. This is at least an undesirable if not a totally unacceptable condition. Limitations of the 490 for Apollo/CCATS are confirmed.

The 494 result of 13.3% does not on the surface represent the number required to satisfy the objective stated above. To truly reflect the percentage of 494 capacity required to support a GEMINI mission within a CCATS configuration, consideration must be given to network changes and software Executive-System changes applicable to GEMINI during the CCATS time period but not capable of being measured at this time. Discussions with Univac personnel, however, indicate that no significant loading changes (perhaps even a decrease) should be associated with these factors. As a result, 13.3% is herein considered valid for the GEMINI component of total CCATS loading.

Assessment of Switcher Cycle Count Technique

Such an assessment was indicated previously as closely associated with the results of peak loading measurements. Although there exist no rigorous means of assessing the validity of the measurements taken and thus of the measuring technique itself, the general characteristics of the recorded loading data for both the 490 and 494 when viewed with a knowledge of input traffic characteristics may be interpreted as reason for confidence.

First of all, fluctuations in the number of Switcher cycle counts recorded for each 1 second interval exhibited no regular pattern. This would be expected on the basis that, although the same input data sources were maintained throughout the measurement period, processing demands within any given second is a random variable when dealing with non-synchronized data sources; i.e., the degree of "demand coincidence" viewed on a 1 second time scale is random. In addition, the magnitude of such fluctuations about the average loading appeared consistent with the expected degree of "demand coincidence;" i.e., variations were significant from a percentage viewpoint but did not exhibit erratic spiking (an exception is discussed subsequently). Calculation of the highest and lowest loading levels recorded for any single second (again ignoring the exception discussed below) yields the following:

Machine	Highest Point	Lowest Point	Average
490	79.1	66.3	68.0
494	17.3	6.7	13.3

In summary, empirical results appear to support the "paper validity" of the techniques.

An exception to the general pattern of results discussed above should be noted. Although this exception does not invalidate any of the statements made above, it does illustrate the importance of peak loading duration as well as peak loading level to meaningful interpretation of loading data. Figure 2-8 provides an example of load "spiking" as measured on the 494 during the peak traffic situation. Note particularly the load percentage range bounded by the lowest and highest values measured for all data outside of the "spike" under consideration. Data points associated with the "spike" exist for only 3 seconds at levels not bounded by this normal range. Spikes of such duration must be considered as insignificant operationally; their only impact is a negligible delay of low priority data. The implication is clear; the duration of loading at a particular level must be considered before the significance of that measured level may be understood.

3. Application of Switcher Cycle Count Technique to Achieve An Understanding of Loading Components

Previous results indicated that the subject technique will achieve valid measures of total loading in response to any particular traffic situation. This portion of the analysis is concerned with the use of the same technique to view overall loading in terms of various loading components. The goal as defined earlier is development of a predictive capability relative to overall system loading in a peak operational traffic situation.

Before investigating the usefulness of a particular technique, the general form that such a predictive capability would take must be defined. The approach would be to develop a family of loading curves, each member describing the percentage of computing capacity used to process a particular type of input data as a function of the "volume" of that data. More specifically, based on the fact that any chain of processing events constituting loading may ultimately be traced to an interrupt occurrence indicating the presence of input data, each curve would describe loading as a function of the number of interrupts per second. A separate curve would be required to

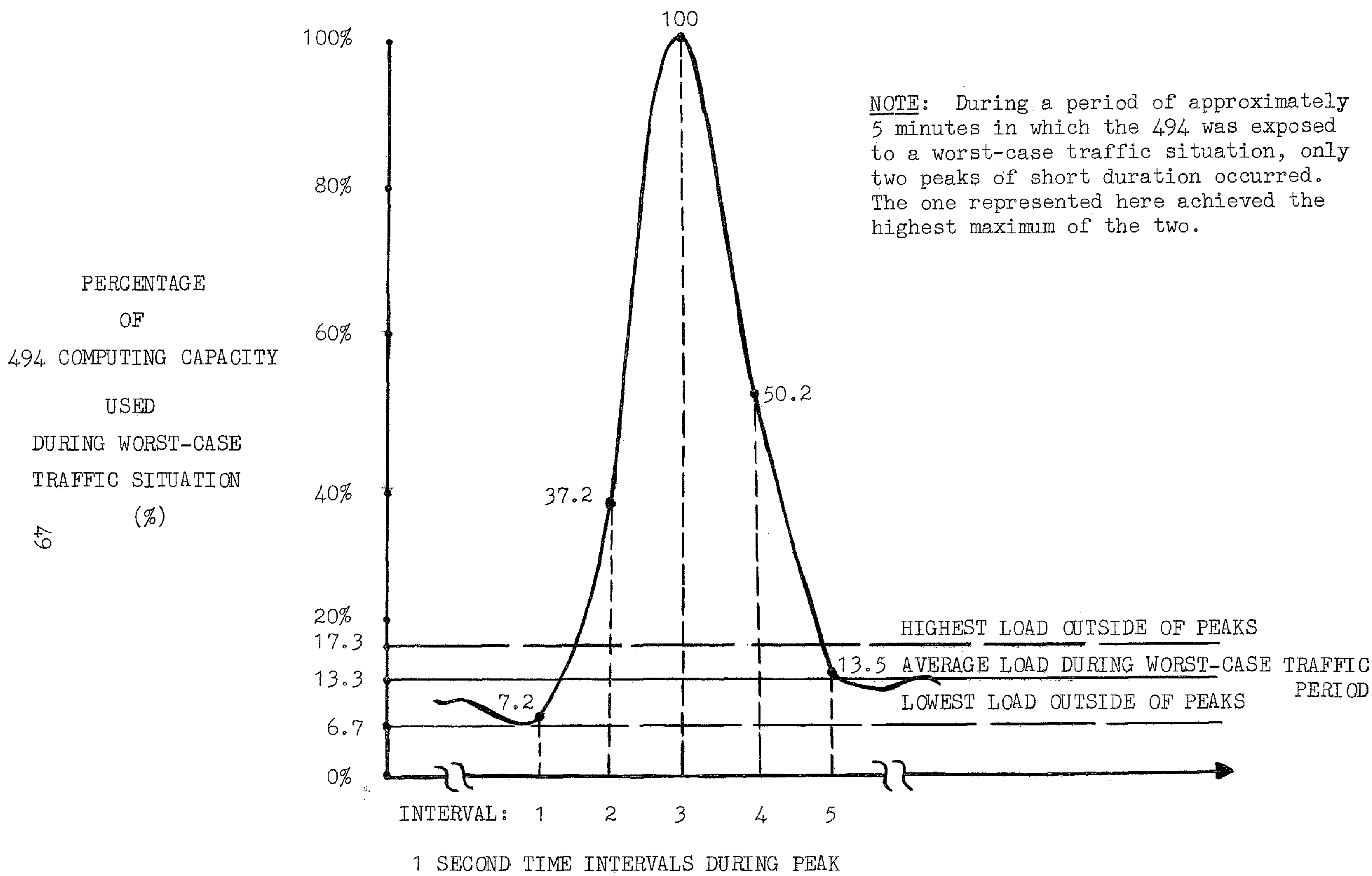


FIGURE 2-8 EXAMPLE OF SHORT DURATION PEAKING EXPERIENCED ON 494 DURING WORST-CASE TRAFFIC SITUATION

describe loading for every chain of software events which is definable as unique in terms of the type of interrupt causing its initiation and of the combination of programs involved in that chain. Such a distinct chain generally exists for each type of data input to the system except in those cases where different data types from an operational point of view are processed indistinguishably by the system of interest. (For instance, all Buffer/Formatter and DCU-R data inputs to the present system may be viewed as initiating the same software chain.) A further breakdown within the resulting family of curves may be required to reflect the sensitivity of loading measurements, if such sensitivity proves significant, to detailed data characteristics such as message length and the distribution of the same total interrupt rate between physically distinct input lines. In summary, a family of curves describing loading as a function of interrupt rate may be defined but only with careful consideration of the specific curves required.

Each loading curve would be "drawn" by collecting empirical data over a wide enough range of interrupt rates to permit meaningful extrapolation to non-empirical data points for predictive purposes. A baseline point would be established on each curve corresponding to the interrupt rate associated with a peak operational traffic situation. The sum of the loading levels associated with all such baseline points would, with the incorporation of any form factor required to reflect the whole as unequal to the sum of its parts (discussed in more detail below), represent overall system loading for the peak operational traffic situation. To use the family of curves as a predictive tool in estimating the impact on overall loading of a newly defined (or potential) requirement, it would be required only to convert this requirement to an increased interrupt rate, move to the appropriate loading point on the appropriate curve, sum again with unaffected components at their baseline level, and apply the necessary form factor to achieve the desired result.

Note that to prevent the compounding of any inaccuracies associated with non-empirical data points, prediction and measurement must be used in an iterative cycle. Once a previously predicted requirement has been implemented, empirical data may be taken to specifically establish a new baseline point on the appropriate curve. Achievement of new baseline points in this iterative manner limits predictive inaccuracies to those associated with only a single "jump" on a loading curve. This feature, of course, implies continuing use of any loading measurement technique.

Although limited availability of both MCCH facilities and analysis time precluded a complete investigation of the applicability of the Switcher cycle count technique to the predictive approach described, preliminary results in the three areas described below are considered indicative. Appendix B should be consulted for any description of measurement configuration details or data reduction details not included in the following paragraphs.

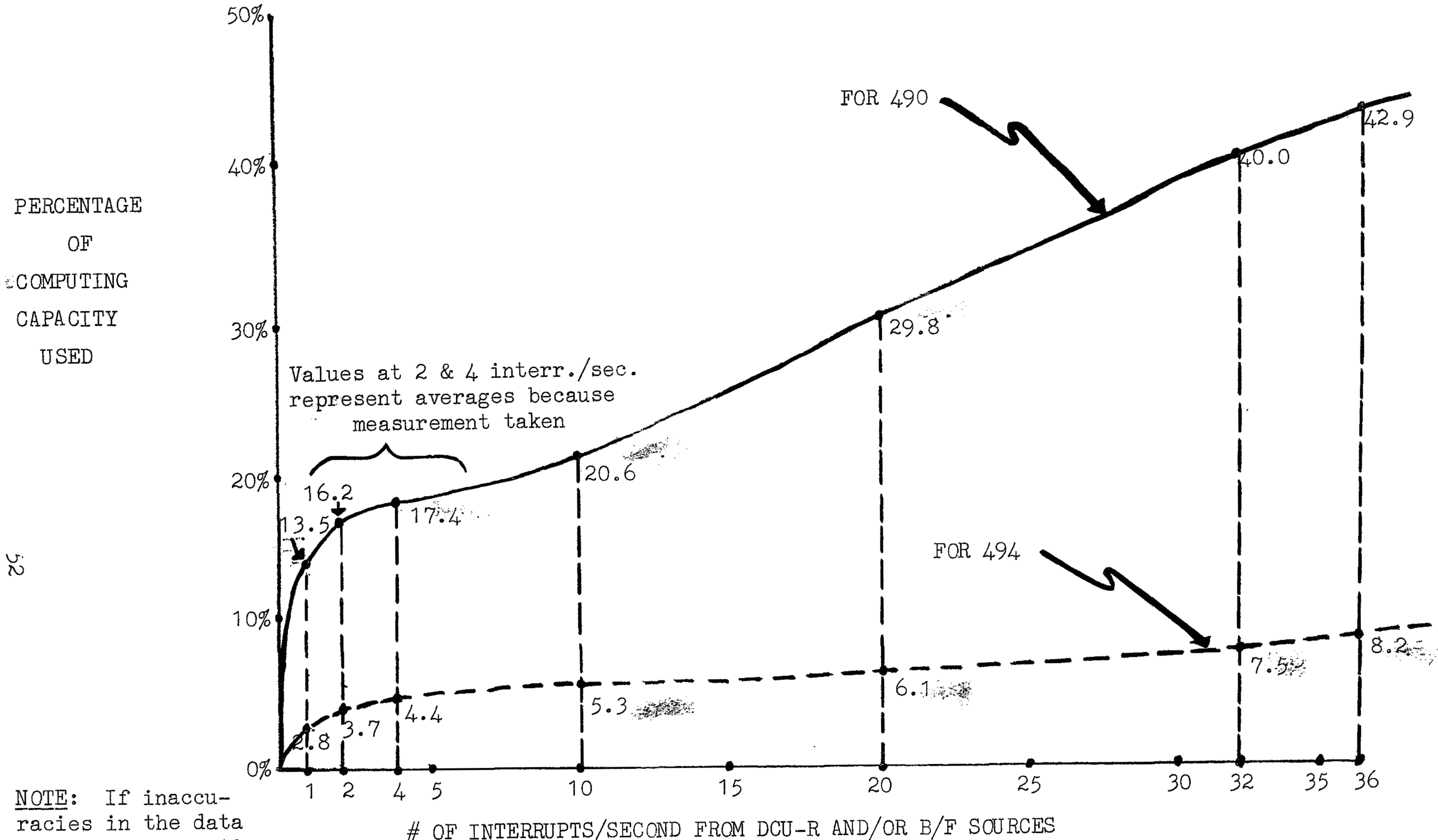
Construction of Sample Loading Component Curve

Because individual loading curves are integral to the predictive approach described, it was considered important to generate a sample of such curves. In addition to investigating the technique itself, it was desired to confirm at the same time that resulting loading curves lend themselves to extrapolation; i.e., their behavior is not erratic (this certainly would not be expected). Figure 2-9 presents the results of exposing both the 490 and the 494 processors to a series of loads involving successively higher interrupt rates as indicated by the empirical data points. Each data point was associated with a specifically defined combination of Buffer/Formatter and/or DCU-R (GELB, IP, BDA) inputs. These data sources (static data employed) were selected for the example because they 1) initiate the same software chain and 2) are characterized by a fixed number of interrupts per second. Implicit in this curve is the assumption that loading for the software chain of interest is not sensitive to message length or to interrupt distribution between input lines; different interrupt distributions and message lengths were required to permit measurement over the relatively wide range of interrupt rates.

Viewing this curve in itself makes the general approach described above look very promising. As might be expected, results at the lower end of the interrupt range indicate a certain amount of loading overhead which is not a function of interrupt rate. Also as expected, the curve becomes essentially linear beyond a certain point, 4 interrupts/second in this case.

Sensitivity to Variations in Detailed Data Characteristics

The possible existence of such sensitivities being significant was noted previously with the possible impact being expansion of the size of the family of loading curves to a number greater than the number of distinct



NOTE: If inaccuracies in the data were better quantified, a linear characteristic for interrupt rates >4 seconds might be expected.

FIGURE 2-9 EXAMPLE OF A CAPACITY USAGE "BREAKDOWN" CURVE INDICATING CAPACITY USAGE VS. INTERRUPT RATE FOR A SELECTED SOFTWARE "MAJOR CHAIN" software chains. This issue was addressed by collecting data for more than one configuration at each of two interrupt rates. In particular, different combinations of Buffer/Formatter and DCU-R data were employed at both 2 and 4 interrupts/second. (Loading values in Figure 2-9 at these two rates represent averages of the different loading values obtained.) Three different configurations characterized by 4 interrupts/second and two different configurations characterized by 2 interrupts/second were investigated, different configurations at the same rate distinguished only by message length, interrupt distribution by line, or interrupt distribution within a one second time period. See Appendix B for specific configurations and the associated results.

Unfortunately, all that can be said at this time is that the results were inconclusive: they failed to evidence any regular, predictable patterns for the sensitivities of interest. Considering only selected measurements, apparent consistencies in terms, for example, of increase loading with message length may be found. The number of samples, however, is considered insufficient to support conclusive results. More importantly, however, basic inconsistencies may be found as well. In response to the same two configurations, the 490 and 494 behaved conversely in one case. Another case indicated an inverse relationship between loading and interrupt rate, etc.

As stated, these results must be considered inconclusive. Certainly the presence of basic inconsistencies mitigates any optimism about the predictive approach under discussion. It should be emphasized, however, that possible explanations for these exist which do not defy the usefulness of the approach or measurement technique. For instance, apparent inconsistencies may exist only because the associated sensitivities are not well enough understood. Perhaps these inconsistencies exist because the distinctions between configurations and their associate interrupt rates were not marked enough to overshadow the random error characteristics of the measurement technique itself. This latter statement of course challenges the merit of any results achieved, but further analysis of the inaccuracies involved and their accumulative effect on an overall loading prediction may indicate that these are acceptable for the purposes envisioned. In this regard, it might be necessary to worst case all curves based on an understanding of the errors involved and accept the eventual result as providing a safety margin.

Derivation of a Whole vs. the Sum of the Parts Form Factor

Results in this area must be considered particularly critical. Because any individual loading curves must be generated in an environment in which no other traffic exists when using the Switcher count technique, results using this technique do not directly reflect the impact on overall loading of the fact that, when viewed on a fine time scale, traffic from a particular source is received and processed randomly in time relative to traffic from other sources. Essentially this impact may be understood by viewing the loading associated with different portions of the total traffic to be additive only to the extent that the durations of these loading components overlap. In other words, overall loading experiences an averaging effect due to the less than 100% overlap of various loading demands on the system. As a result, the sum of all loading components derived using the count technique would be expected to be greater than the overall loading measured with all traffic being input during the same measurement interval. This implies the need for a form factor which permits reliable calculation of expected overall loading from the sum of all loading components as individually measured. Otherwise prediction may not be achieved.

Use of the form factor discussed would occur after curve summation has been achieved with any predicted increases in loading included on a curve-by-curve basis. At this point, the summation would be multiplied by the form factor to achieve the expected overall loading. For purposes of this report, data was collected to permit calculation of this form factor as X = Sum of Loadings Measure for Each of All Overall Load Components/Overall Loading Measured. Appendix B may be consulted for the particular configuration employed to calculate X.

X was calculated for three separate cases in which the configurations permitted regarding one traffic configuration as the composite of more than one other configuration. Loading component measurements were taken for all traffic included in the peak configuration considered as the composite of four separate configurations. This case was considered most meaningful because the degree of "loading overlap" reflected should be representative for the variety of data types and rates generally associated with a peak traffic situation (the only situation considered herein to be of predictive significance). Results obtained are as follows:

For 490, X = 0.62

For 494, X = 0.485

Note that the lesser value of X for the 494 would be expected; faster machine = shorter duration of various loading components = lesser overlap. Regarding the validity of these particular numbers, however, again one must conclude that more data samples are required to permit such an assessment. The fact that the other calculations made resulted in different values for X (see Appendix B) was predictable; the exact quantitative nature of the variations can not be commented upon without more data.

Use of the form factor X in support of continuing analysis would involve an iterative cycle of prediction and empirical measurement like the one discussed previously. In this case, the X empirically derived for the existing configuration would constitute a baseline value and would be used to achieve a predicted value for overall loading. A new empirically derived X would be calculated following implementation of any new requirements. It is recognized that this report presents only very preliminary results in this area; considerably more analytical effort will be required if further development of the technique considered warranted.

Inaccuracies Involved in Technique and Resulting Predictions

Because a detailed investigation of the inaccuracies involved in the above results or in any future results has not been included within this analysis, comments can be made herein only about the nature and importance of such an investigation. First of all, the inaccuracies inherent to the Switcher count technique itself must be considered by detailed theoretical considerations of the nature of the Switcher job scheduling operation. Secondly, the inaccuracies of a single loading curve must be considered, not only in terms of the measurement technique, but also in terms of any sensitivities not reflected in a separate curve. Such considerations will require collection of more extensive data related to loading sensitivity as discussed previously. Thirdly, the inaccuracies accompanying predictions using this approach must be considered in terms of inaccuracies associated with determining X. The point of identifying the various types of inaccuracies is not to downgrade the usefulness of the approach, but to emphasize the importance of understanding these before interpreting any results obtained.

Alternative Techniques

Certainly a variety of other techniques exist to achieve the results analogous to those obtained using the Switcher cycle count method. These may be discussed in two groups: theoretical techniques and simultaneous recording of loading components as well as overall loading measurements. The first is not considered truly comparative; theoretical techniques certainly have merit when empirical techniques are not feasible or practical, but their merit must be considered lesser if empirical techniques are available. Simultaneous recording, on the other hand, is an empirical technique whose merits may be directly compared with those of the Switcher count method. This general approach as defined herein includes all forms of on-line recording which collect detailed data describing when and for how long various portions of the software package operate. (As in the case of RTCC recording of its own processing statistics, this approach often involves collection of performance data in addition to that required solely for achieving a breakdown of overall loading.)

Considering utilization of the simultaneous recording method as a predictive tool in the sense of the approach described previously, the same problems related to loading sensitivity exist. An important potential advantage, however, is the ability to collect data for individual loading curves while other traffic is being input to the processor. Result: measurements obtained reflect X directly. The importance of this advantage must be determined only with an understanding of the difficulty of reliably defining X using the Switcher count technique. This advantage then must be weighed against the costs and complexities of incorporating a simultaneous recording capability in the software package of interest, CCATS in this case.

Without reaching a final conclusion it may be stated that a predictive tool appears to have significant merit in the NASA environment of changing and increasing requirements. Steps to provide such a tool should include consideration of the trade-offs between the two types of empirical techniques discussed, resulting in a decision to implement one or a combination of these techniques.

4. Results Relative to a 494 vs. 490 Computing Capacity Ratio

Results in this area are straightforward. They have been calculated as the ratio of 490 computing capacity required for a particular configuration to the 494 capacity required for the same configuration. Calculating this ratio for all configurations employed and averaging, the following result is obtained: 4.53. Such a ratio is influenced by the nature of the particular configuration in terms of the mix of various instruction types and the utilization of certain memory accessing features unique to the 494. Because the peak traffic situation should be more representative of these factors as applicable to communications processing functions, one might consider the ratio for the peak load situation alone to be more significant. This was 5.1.

In any event, a factor of approximately 5 appears to describe the increased execution speeds associated with the transition from the 490 to the 494. Note that this figure corresponds very closely to the "advertised" improvement ratio.

Conclusions and Recommendations

The most significant conclusions are tabulated below in a summary form. Certain of these actually consist of a summarization of analysis results.

- Use of the Univac 490 hardware in a CCATS configuration would incur processing delays of abnormal duration and the possibility of data loss in the case of peak traffic for two simultaneous missions.
  Basis: Approximately 68% of 490 computing capacity is required to support peak operational traffic for a single GEMINI mission.

- Use of the Univac 494 hardware in a CCATS configuration would appear to provide a significant operating margin in terms of unrequired computing capacity.
  Basis: Approximately 13.3% of 494 computing capacity is required to support peak traffic for a single GEMINI mission.

- The Switcher cycle count technique employed for this analysis will provide meaningful measurement, of overall system loading to answer the question "what portion of my total capacity am I presently using?"

- Use of the Switcher cycle count technique and the family of loading curves approach to provide approximate predictions in response to the question "what portion of my total capacity will I be using once these new requirements have been accommodated?" appears promising. Before any technique or approach is implemented to provide a predictive capability, however, the Switcher cycle count technique must be further investigated in areas delineated above and the other alternatives mentioned should be evaluated in a comparative fashion. Combinations of techniques should be considered.

- For a communications processing application, a factor of approximately 5 describes the speed of execution advantages associated with Univac 494 vs. Univac 490 processing hardware.

Two related recommendations are derived from these conclusions: it is recommended that -

- The Switcher cycle count recording capability be permanently installed in the CCATS software package in a form appropriate to support continuing analysis of computing capacity being used. (Details of the form do not warrant discussion in this report.)

- Further empirical data be collected to support a conclusive investigation of the usefulness of the Switcher cycle count technique to provide a loading prediction capability. (The specific definition of data to be collected must be achieved in light of those areas requiring investigation as delineated in this analysis.)

- An effort be commenced to examine other possible means of providing the ability to conduct on-going analyses of system loading, the objective being the ability to support selection of a particular technique (or combination of these) for final implementation.

Note that conclusions and recommendations related to the detailed mechanics of data reduction and collection have in some cases been implied by this analysis, but are not considered of enough general significance to be included in this paragraph.

SECTION IV

SUMMARY OF RECOMMENDATIONS

The effectiveness analysis of the Communications System described above may be viewed as resulting in a two-part product. One part consists of results and conclusions derived therefrom intended to provide an analytic description of present system performance or of expected CCATS performance, emphasis being on the former by necessity. This part of the product is not summarized in this paragraph; significant results and conclusions are delineated above in summary fashion for each portion of the analysis. The second part of the product consists of a series of recommendations with the common goal of insuring that areas considered to require further analytic effort are identified. These recommendations are tabulated below in summary form with reliance on other portions of this report to provide supporting information. The repetition involved is considered justified by the convenience of identifying actions to be taken. Specifically, it is recommended that -

- The Switcher cycle count recording capability be permanently installed in the CCATS software package to support continuing analysis of processor loading.

- Alternative techniques providing loading measurements, including the Switcher cycle count technique, be comparatively evaluated and that a technique or combination of techniques be implemented and utilized to provide a predictive capability relative to CCATS processor loading.

- An analysis be conducted of the utilization by CCATS of both core and peripheral storage hardware in terms of the types and quantities of data stored, this analysis providing an indication of the growth characteristics of the CCATS system.

. Time delays and related telemetry data handling issues (e.g., time homogeneity of data samples) considered significant by NASA be analyzed for Apollo using the techniques employed in this study, and that this analysis be directed toward the related issues of data handling adequacy from an operational viewpoint and data handling efficiency from an engineering viewpoint.

APPENDIX A

A FRAMEWORK FOR SYSTEMS ANALYSIS AND EVALUATION

INTRODUCTION

As discussed in the main body of this report, analysis in the Communications System area emphasized the selection of system characteristics for analysis based on their significance. To provide a technique for assessing "significance" in support of this selection process, an analytic framework was developed to make explicit what otherwise would have been left to system experience and "intuition." Because the resulting framework appears to have merit as a tool for systems analysis and evaluation in general and because experience with this tool in the Communications Systems area has met with practical success, this appendix is provided. This appendix is intended to be sufficiently descriptive to permit a general understanding of the framework being presented, but not sufficiently detailed to permit a thorough evaluation of the framework as a system analysis and evaluation tool; this appendix constitutes only a starting point for such an assessment.

PURPOSE

Before describing the analytic framework itself, the advantages generally associated with an explicit approach to systems analysis/ evaluation as opposed to total reliance on experience and intuition should be stated. These are -

- Contribution of a unifying influence to all analysis activity which enhances the ability to treat total system issues.
- Provision of a commonly-accepted and consistent set of criteria against which to evaluate proposed design alternatives.
- Reduction of the probability that significant areas of interest will be overlooked.

Influencing the development of the subject framework was the constraint that analysis for purposes of this report would be conducted without a tabulation of specific mission requirements from which areas of interest could be directly derived. If such a constraint were truly unique and if the resulting approach were totally dependent on that constraint, the approach certainly would not be useful for a general systems analysis/evaluation application. It may be contended, however, that such a constraint is not unique although of varying degree in different situations. More specifically, in an environment of changing and somewhat unpredictable requirements, it is desirable to have a means of looking at a system which is not totally dependent upon a knowledge of specific, detailed requirements. The attempt herein to satisfy this desire is based on the distinction between specific mission requirements and requirements categories.

Because the concept of requirements categories provides a starting point for the analytic approach described, this concept should be well understood. Simply stated, it merely reflects the fact that when viewing the wide variety of specific requirements that may be stated for the MCCH or a similar system, one begins to identify certain basic characteristics of these which appear repetitiously and provide a common thread. Study of such basic requirements characteristics leads to the conclusion that these may be tabulated in such a way that <u>any specific requirement</u> may be described by a quantitative combination of these, the resulting tabulation being designated as a list of requirements categories.

An example might help to clarify the above discussion. A specific requirement might be to decommutate an additional Apollo TLM format received via a new wide-band link between a remote site and the MCCH. The associated requirements categories may be stated as -

The requirement to respond to

- An increased number of different TLM formats to be handled within the MCCH

- An increased number of wide-band data inputs into the MCCH

Although establishing a list of requirements categories may be trivial conceptually, it must be accomplished carefully and with a firm understanding of the system if the result is to be comprehensive enough to truly cover all possible specific requirements.

QUESTIONS TO BE ANSWERED

If any framework is to prove useful as a systems analysis/evaluation tool, it must be evolved with the ability to provide answers to certain types of questions as an objective. Without attempting to define terminology too closely at this point, the subject framework is intended to provide assistence in answering two types of questions about a system as follows:

- How well is the present system doing its job?

  (MCCH system functions regarded as constant. Specific questions generally some form of "how reliably? or "how rapidly?")

- What ability does the system have to perform its present function for more data?

  ("More data" in the very general sense required to cover increased traffic rates, increased number of formats, etc. "How efficiently" is considered herein as within the scope of this question although it could just as well be considered a further specification of "how well?")

If one addresses the issue of why these questions are of interest, he immediately encounters the fact that each is related to a set of demands upon the system and the question itself expresses interest in how well the associated set of demands may be met. In particular, the two types of questions stated above are related to what are referred to herein as "Performance Demands" and "Augmentation Demands," respectively. These two demands types are viewed as the starting point of the subject framework with the objective being a means of looking at the system which permits analysis of how well such demands may be met.

Note that demands are discussed herein as levied upon the MCCH with no prior knowledge of whether or not these may be easily accommodated. This decision to ignore the trade-offs which exist in practice between capabilities and requirements not made purely to simplify discussion.

FRAMEWORK DESCRIPTION

Figure 1 describes both the framework being discussed and the environment in which this framework must be viewed in terms of sources of demands upon the MCCH, processes involved in response to changing functions, and the impact of design alternatives. This paragraph is devoted primarily to the framework itself.

That portion of Figure 1 contained in the double lines constitutes the framework which is the primary subject of this memorandum. Indicated within these lines are successive stages of the framework designed to permit selection and analysis of those system characteristics related to the satisfaction of Performance and Augmentation demands. Portions of Figure 1 outside of the double lines are provided primarily to indicate the potential usefulness of the proposed framework in addressing questions other than those directly associated with Performance or Augmentation Demands. Figure 1 is used as a basis for the descriptive information provided in subsequent paragraphs with emphasis on the "framework portion." Examples are provided as appropriate to indicate the product of successive stages within the framework, but descriptive information is kept to a minimum with comments provided only when the figure is considered inadequate.

Before the successive stages of the framework starting at A may be understood, a point relative to the derivation of "MCCH Level Requirements Categories" should be explained. First of all, demands upon the MCCH are viewed as associated with two MCCH Interfaces - the MCCH interface with the "External World" and the MCCH interface with "Internal Mission Personnel" (both Flight Controller and Support Groups including M & O personnel). Both of these demand sources may be viewed as having both a physical data interface and an operational/mission requirement interface with the MCCH (see Figure 1). Demands being "input" to the MCCH across these interfaces become requirements from the point of view of the MCCH itself. In summary, demands from two sources are viewed as levying requirements upon the MCCH as indicated in Figure 1.

Stage-By-Stage Framework Description ("Stages" identified by circled letters in Figure 1)

STAGE A - Would consist of a tabulation of requirements categories at the MCCH level divided, as one possibility, into various major and minor groupings to reflect the structure of the demand interfaces.

A sample tabulation with examples is provided as follows:

MCCH Level Requirements Categories

I. Augmentation Requirements Categories

A. As associated with the External World Interface

1. Data Interface Requirements Categories for each data type, the requirement to respond to

a. Increased number of different data formats to be handled.

b. Increased number of sources/destinations.

c. Increased message rate.

----------etc.

2. Mission/Program Scheduling Requirements Categories respond to requirements for

a. Increased degree of simultaneous mission support capability.

b. Reduction in MCCH "turn-around" time.

B. As associated with the Internal Mission Personnel Interface

1. Data Interface Requirements Categories respond to requirements for

a. Increased number of selectable displays of a particular type.

b. Increased number of positions supportable by computer-driven display surfaces.

----------etc.

2. Operational Requirements Categories respond to requirements for

a. A reduction in the time delay between MCCH receipt and MCCH display of a particular data type.

b. A reduction in the probability of display of data of a particular type containing an error.

----------etc.

II. Performance Requirements Categories

A. As associated with the External World Interface requirements to

1. Achieve mission "turn-around" within the MCCH within a specified period.

2. Accomplish support of specified simultaneous mission configurations.

----------etc.

B. As associated with the Internal Mission Personnel Interface requirements to

1. Display received data within a specified period of elapsed time since receipt by the MCCH.
2. Process and display particular data type within the MCCH allowing only a specified level of undetected error probability.

----------etc.

Two observations may be made relative to this sample tabulation. Firstly, the fact that Performance Requirements Categories appear to be a derivative of Augmentation Requirements Categories related to "how rapidly? how reliably?" is more than coincidental. Further investigation indicates that this relationship between the two groupings is a byproduct of the way in which Performance and Augmentation Demand types have been defined.

As a consequence, expressions of certain augmentation and performance characteristics will take identical form with the viewpoint of the user providing the only distinction. For example, one might produce a curve showing TLM time delays as a function of traffic loading in the system. One point in this curve might represent present performance while the characteristics of this curve beyond this point would portray the augmentation characteristics of the system.

Secondly, it is recognized that although the above statements of performance requirements categories imply the known quantification of such requirements, a performance analysis might often consist of describing a performance characteristic of a system in an environment lacking any quantitative standard against which to compare the result.

STAGE B - Derived simply from Stage A as indicated in Figure 1. Considered to be one of the most important products of the framework approach because of the desirability of establishing a set of effectiveness criteria against which any system may be assessed regardless of the functions being performed or of the mechanization technique employed. The following tabulates effectiveness criteria associated on a 1-to-1 basis with certain of the sample requirements categories tabulated above to indicate the ease of generating such criteria once a comprehensive understanding of the various categories of system requirements is understood.

Related Reqmnt Category	Effectiveness Criteria
From an Augmentation Viewpoint,	
I.A. 1 a. above	Ability to accommodate new formats for each data type as defined in terms of the relevant format characteristics.
I.A. 1 b.	Ability to accommodate an increased number of data sources/destinations for each data type.
I.A. 2 a.	Ability to increase the number of simultaneous mission configurations which may be supported.
I.B. 1 a.	Ability to accommodate an increased number of selectable displays.
I.B. 2 a.	Ability to achieve a reduction in data time delays incurred within the MCCH for each data type.
From a Performance Viewpoint,	
II.A. 1	Ability to achieve mission turn-around within a specified time period.
II.B. 1	Ability to display data of a particular type within a specified period of elapsed time since receipt by the MCCH.

Note that all effectiveness criteria are stated above as an "Ability to -- " with the understanding that the ability of interest must be analyzed in an environment in which the functions performed relative to each data type remain constant. At this point, however, effectiveness criteria are not sensitive to which portion of the MCCH performs which functions.

STAGE C - Although this stage has a more minor significance it appears in the framework as distinct from STAGE B to permit the selection from the list of overall MCCH criteria included at B of only those criteria which are relevant to each particular MCCH portion. Omissions are obviously warranted, for instance, in cases where an effectiveness criterion viewed on a per type of data basis in STAGE B relates to a type of data which is not handled by a particular MCCH System. As indicated in Figure 1, the definition of these cases requires a knowledge of the way in which overall MCCH functions have been allocated between different MCCH systems. Note that the presently accepted delineation between portions of the MCCH has been reflected and also that an Intersystem Effectiveness Criteria grouping appears to provide recognition that the ability to respond to certain types of requirements may be reasonably viewed only on an intersystem basis. End-to-end time delays within the MCCH certainly fall in this category although one could consider these delays to have a per system component with the total picture achieved by simple summation.

STAGE D - As indicated in Figure 1, this stage applies to the task of proceeding from C only for those effectiveness criteria associated with Augmentation Demands.

This stage reflects the fact that for any ability of the system associated with system growth, a primary constraint on this ability may be identified based on the detailed nature of the system. Emphasis should be placed on the necessity to define only the primary constraint. Regardless of the nature of a particular system configuration, one will generally be able to define several constraints dictated by the system design which apply to the same ability. The desire to limit analysis to the primary constraint is derived from the fact that it appears impractical to examine system characteristics in terms of all of the definable constraints.

To make the transition from C to D, a thorough knowledge is required of the mechanization techniques employed in the system to implement the assigned functions. Perhaps it is useful to view D as a tabulation of primary constraints related to system level (as opposed to MCCH level) effectiveness criteria on a 1-to-1 basis. An example of the "entries" in such a tabulation is shown below. The entry for both the existing system and the CCATS system relative to the same effectiveness criterion is provided to indicate the sensitivity to mechanization technique.

Effectiveness Criteria for Comm. System - Ability to accommodate an increased number of data sources/destinations for each data type.

Defining this ability as simultaneous accommodation of different TLM formats, the following results are obtained:

> For the existing system, the number of different TLM bit streams which may be handled simultaneously is equal to the number of ground stations. Simply, therefore -
>
> Primary Constraint = No. of Ground Stations

For the CCATS system, the number of different TLM bit streams which may be handled simultaneously is limited primarily by the amount of storage reserved for the buildup of TLM parameter tables. (Used for purposes of example - not necessarily realistic.) Therefore -

<u>Primary Constraint</u> = Amount of core storage available for TLM parameter tables.

<u>STAGE E</u> - This stage represents the result of determining the most appropriate way of describing that characteristic of the system associated with each effectiveness criterion in C. Such a description may be considered to constitute an expression of the ability upon which the effectiveness criterion is based.

Treating this stage relative to effectiveness criteria in the augmentation grouping and noting the significance of D as described above, it may be seen that the "expression of ability" becomes an expression of the primary constraint when augmentation characteristics are of interest (see Figure 1). For example, considering the particular primary constraints identified in the description of D, the expression would consist simply of the number of ground stations for the existing system and of a curve of core storage usage vs. the number of TLM streams simultaneously processed for CCATS. When performance characteristics are of interest, achieving E is just a matter of determining the means of expressing such characteristics in a way which best facilitates interpretation from an operational point of view.

<u>STAGE F</u> - The transition from E to F constitutes the actual detailed analytic work. No framework could or should dictate analytic techniques at this level; these are based on the nature of the issue being addressed and the data available to support analysis.

<u>Framework Environment</u>

The portions of Figure 1 outside of the double lines are considered herein as the "framework environment" and are added to indicate how the framework itself may be considered to be related to system viewpoints/ interests which in itself does not specifically cover. In particular, the

the framework specifically reflects only Performance and Augmentation viewpoints and reflects these only once the totality of MCCH functions h have been defined and a design alternative has been selected in terms of a particular allocation of functions within the MCCH and of a particular mechanization technique for each function (or set of functions). On the basis of this summary statement of the limitations of the framework, other portions of Figure 1 specifically relate to a particular type of demand not reflected within the framework and to the interrelationship between the framework and the establishment of design alternatives in terms of varying functional allocations and/or mechanization techniques.

Functional demands appear to be the only major demand type not covered within the scope of the framework itself. Figure 1 indicates the fate of such demands in a manner which should be self-explanatory. Most important is the fact that once the totality of MCCH functions has been defined, the next step is to define a design alternative in the terms noted above and as shown in Figure 1. Also as indicated in Figure 1, definitions of the two features - functional allocation and mechanization technique - of a design alternative serve as inputs to the process of proceeding through successive stages of the framework. If one is concerned with new system design alternatives in response to a new definition of MCCH functions in response to functional demands, the functional allocation and mechanization techniques features of these alternatives must be defined before they may be investigated/compared in terms of their performance and augmentation characteristics via the framework approach.

Non-framework portions of Figure 1 other than those associated with the response to functional demands merely indicate that an iterative cycle of design alternatives and systems analysis, once "triggered", will not terminate until the user is satisfied with both the augmentation and performance characteristics of the system. (Obviously, user satisfaction must be tempered by cost and schedule considerations which are not covered by the proposed framework and by the extent to which explicit statements of performance and augmentation characteristics are made available.) This cyclic behavior implies that the framework approach could prove useful in providing a common and consistent set of criteria against which to evaluate any design alternative whether or not such an alternative may be traced to new functional demands.

RECOMMENDATION FOR FURTHER DEVELOPMENT AND USE

It is strongly recommended that the approach described herein or some other analogous approach be developed for use as a working tool in support of a continuing systems analysis and evaluation activity. To achieve this end, significant review by all parties concerned will be required. Critiqueing by NASA should specifically include testing of the framework against all questions of user interest to uncover any significant areas not covered. Such critiqueing, of course, would follow further work by MITRE personnel to evolve the framework to a more final form.

Once an agreed upon framework has been established and is commonly understood by both MITRE and appropriate NASA personnel, the framework might be employed to the following ends:

- To permit the selection of specific augmentation and performance characteristics warranting detailed analysis as part of an on-going systems analysis/evaluation effort, relative to the existing configuration (at any point in time).

- To provide a commonly-accepted and consistent set of effectiveness criteria against which any design alternatives/proposals may be evaluated in terms of their relative augmentation and performance merits. (Alternatives may involve only a new mechanization technique, only a new functional allocation, or both.)

- To encourage the breakdown of NASA-wide requirements into those components which permit evaluation of their impact upon the performance and augmentation characteristics of the MCCH.

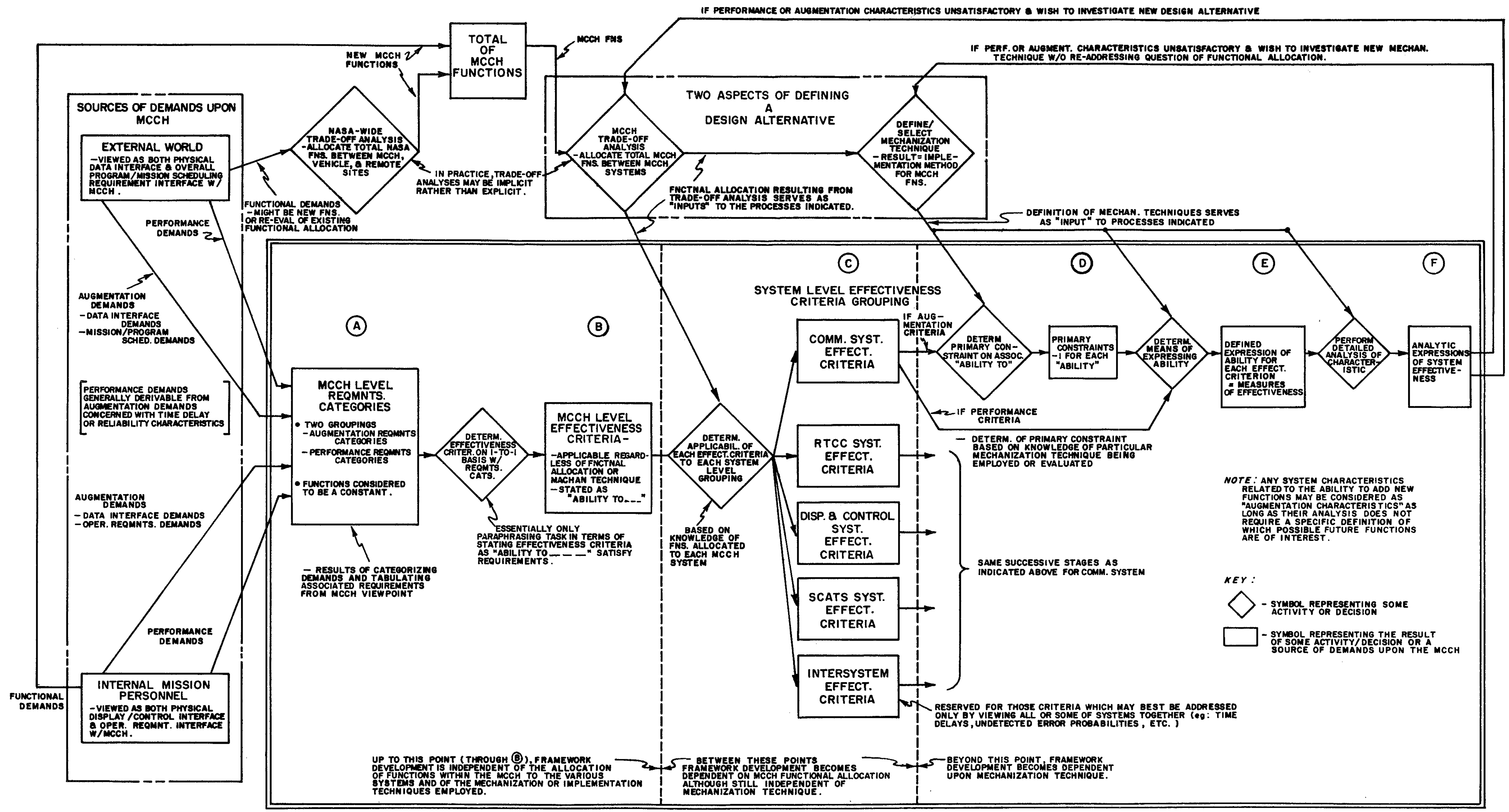


Figure A-1 - FRAMEWORK FOR MCCH SYSTEMS ANALYSIS/EVALUATION & ASSOCIATED "ENVIRONMENT"

APPENDIX B

BACKUP DATA FOR COMMUNICATIONS SYSTEM ANALYSIS

PURPOSE

The purpose of this appendix is to provide technical data and discussion in support of the analyses described in the main body of the report to the extent such information is not contained in the report itself. Information presented in this appendix is not in itself meaningful; it must be understood in light of the main report itself.

BACKUP DATA FOR TLM DATA HANDLING ANALYSIS

Data in this paragraph is provided in support of Figure 2-1. The means of calculating both the Cycle Sync and Mechanization Delays presented in Figure 2-1 is described.

Propagation Delays

This category of delays may be treated in a group. Propagation delays between components or stages in the same facility were considered negligible. Propagation delays between the vehicle and a remote site (any remote site as an approximation) and between the remote site and the MCCH were computed using a worst-case TELCO propagation figure of 60,000 miles/second. Whether or not this particular worst-case figure unfairly exaggerated the propagation delay results was not investigated due to the small contribution of propagation delays to total delay. Mileage figures were assumed as follows based on a similar Philco analysis contained in the Telemetry Subsystem data books:

Vehicle to remote site, 200 miles
Remote site to MCCH, 2,600 miles (worst-case)

The particular propagation delays associated with TLM transmission from down-range sites to Cape Kennedy have been included as part of the Mechanization Delay associated with Cape Kennedy as the site wide-band data source.

Cycle Sync Delays

This category of delays may also be treated as a group for descriptive purposes. Cycle sync delays indicated in Figure 2-1 for the vehicle and for a remote site should be self-explanatory based on the related discussion within the main body of the report. Although the nature of Buffer/Formatter and RTCC cycle sync delays should also be clarified by the same discussion, additional information is as follows:

For the Buffer/Formatter, the presently employed output "frame rate" of 1 frame per second was assumed.

Regarding the RTCC, a portion of telemetry processing is accomplished by software which operates periodically on a 1 second basis.

Note that the legitimacy of equating the sum of the averages to the accumulative average for purposes of this analysis is based on the fact that the probability of incurring a cycle sync delay within a range from the worst case to the best case assumes a uniform distribution.

Vehicle Mechanization Delays

These delays and all other mechanization delays were calculated assuming that a full word of telemetry data (8 bits) is required to fully describe a parameter value. This assumption intentionally yields results of a worst-case nature (only 1 bit required to describe a bilevel event) noting 16 and 24-bit digitals as an exception. Specifically, delay approximations were made by viewing the on-board commutation system as 1) required to obtain an 8-bit word for down-linking within the time that the previously-acquired word is being down-linked at the appropriate bit rate and 2) as outputting data from a parallel-to-serial converted at the down-links rate. On this basis, calculations were made using the AGENA down-link rate of 16.384 to provide worst-case results. These were -

$$MD = 2 \left(\text{bits X } \frac{1}{16,384} \text{ secs/bit} \right) = 960 \text{ MSEC}$$

$$= 0.001 \text{ sec.m Figure 2-1}$$

Remote Site Mechanization Delays, Cape Kennedy

These delays were calculated assuming receipt of down-linked data via a down-range site, meaning a duplication of certain processing stages between the original receipt and transmission from Cape Kennedy. In particular, delays were doubled for the following items: ground station, RSDP, TOB, modem.

Ground station delays were calculated by working backwards from the observation that such a device may be viewed as maintaining pace with the input bit rate with the support only a single 1 word (8 bits) serial-to-parallel converter acting as a buffer register. A ground station must, therefore, be capable of processing a word within the time required to accumulate another word at the input line rate. A down-link rate of 51.2 kbps was used for calculation purposes.

RSDP (Buffer-Multiplexer in the case of Cape Kennedy) delays were crudely estimated based on the observation that, due to the continuous transmission characteristic of telemetry information flow, the RSDP is required to keep pace with input data by processing as many TLM words per second as are required to produce a 100% duty cycle on a 40.8 kbps line. The delay derived from this observation is designated the "RSDP Processing Delays." Using reasoning analogous to that presented for vehicle transmission delay, an "RSDP Processing Delay" equal to 8 bit times on a 40.8 kbps line was also calculated and doubled.

Modem and Telemetry Output Buffer were estimated to be on the order of 1 bit time with a total for the two devices of 1.5 msec.

Almost outweighing all other calculations, a "fat" delay of 60 msec was added to reflect down-range receiver delays and down-range to Cape Kennedy propagation delays. This figure was provided as a worst-case by Philco-Houston RSDP personnel. Results of above:

Delay Type	Delay Value
Ground Station	0.4 msec (2 x 0.2 msec)
RSDP Processing	0.4 msec (2 x 0.2 msec)
RSDP X mission	0.4 msec (2 x 0.2 msec)
TOB and Modem	3.0 msec (2 x 2.5 msec)
Additional DR delays	60.0 msec
Total	64.2 = 64 msec

Remote Site Mechanization Delay, High-Speed Site

Using reasoning analogous to the above, calculating a greater transmission delay based on a lower output bit rate (2.0 kbps), and eliminating the need for "doubling;" following are the results:

Delay Type	Delay Value
Ground Station	0.2 msec
RSDP Processing	0.2
RSDP X mission	4.0
TOB and Modem	1.5
Total	5.9 msec = 6.0 msec

MCCH Receiving Modem Mechanization Delay

Approximated at 1 msec.

MCCH PCM Ground Station Mechanization Delay

Calculated as 8 x 1/40.8 using reasoning as presented for remote site ground station delays. Result: 200 microseconds which was "rounded" to 1 msec for summation purposes.

MCCH Directly-Driven Display Mechanization Delays

Because essentially a "hard-wire" exists between the ground stations and an operators display, an approximate delay of 1 msec was assumed with the actual delay being in terms of microseconds.

MCCH Buffer/Formatter Mechanization Delays

Estimated to correspond to a large number of B/F memory cycles requiring 50 usecs plus a transmission delay for 8 bits at the output rate of 4.8 kbps, the latter being approximately 1700 microseconds. Result: a total delay of approximately 1750 microsecond or 2 msec.

MCCH Communications Processor Mechanization Delays

Estimated based on the following components: 12 bits worth of input buffering within a CLT prior to placing in memory, an average time of 1/2 frame transmission time (estimated as 1/2 the time required at line speed to fill a C. P. memory buffer of 159 words) prior to processing being initiated by an interrupt, a time to accomplish processing based on being "in the middle" of the tasks performed within 0.58 seconds (based on the 68% C. P. loading measurement) and a time to output data to the RTCC at 40.8 kbps assuming location in the middle of the 159 word buffer used for direct outputting. Results:

Delay Type		Delay Value
Input CLT Buffering	=	$12 \times \frac{1}{4,800} = 2.5$ msec
Interrupt "waiting"	=	$\frac{159}{2} \times \frac{12}{4,800} = 200$ msec
Processing	=	$\frac{.680}{2} = 340$ msec
Output X mission	=	$\frac{159}{2} \times \frac{12}{40,800} = \underline{24}$ msec
		Total = 567 msec
		≈ 0.6 seconds

MCCH RTCC Mechanization Delay

An estimate of this delay was provided by MITRE personnel performing the RTCC analysis portion of this study and required relatively crude assumptions on the impact of job queueing within the RTCC. Result: 0.2 seconds (including RTCC input buffering at a single 12 bit character).

MCCH Computer-Driven Display Mechanization Delay

The delay employed was based on the assumption of TV displays as a worst-case. MITRE personnel performing the Display and Control System analysis portion of this study provided data leading to an estimate of 18 msec.

BACKUP DATA IN SUPPORT OF THE COMMUNICATION PROCESSOR LOADING ANALYSIS

Measurement Configurations

Configurations are listed in the order in which data was actually collected. During all measurement periods, the Switcher cycle count was recorded at 1 second intervals.

Config. IP	Configuration Description	Approximate Measurement Duration	Loading Results 490	Loading Results 494
# 1	2 B/F Channels: 1 w/ GEMINI data, 1 w/ AGENA "B" data	1 minute	15.6 %	3.5%
# 2	1 B/F Channel w/ Titan data	1 minute	13.5	2.8
# 3	1 IP DCU-R Input	1 minute	18.0	4.3
# 4	1 GE/B DCU-R Input	1 minute	16.7	3.2
# 5	2 GE/B DCU-R Inputs	1 minute	13.3	4.2
# 6	1 BDA DCU-R Input	1 minute	20.6	5.3
# 7	3 DCU-R Inputs (1 each for IP, GE/B, BDA) and 2 B/F Channels (1 w/ GEM, AGENA, Titan, other w/ AGENA "B")	1 minute	29.8	6.1
# 8	All 6 DCU-R Inputs (2 each for IP, GE/B, BDA) and same B/F Inputs as # 7	1 minute	42.9	8.2

Config. IP	Configuration Description	Approximate Measurement Duration	Loading Results 490	Loading Results 494
# 9	Peak Traffic Situation: Config. # 8 plus MDCS inputs (CW Load to ETR, SPC Load to TEX) plus 5 TTY send devices continuously transmitting NASCOM traffic plus 1 TTY send device transmitting a TLM Summary plus RTCC-generated Command Loads and TLM Rebroadcasts	5½ minutes	68.0 %	13.3 %
# 10	Buffer/Formatter Component of # 9	1 minute	20.6	5.3
# 11	DCU-R Component of # 9	1 minute	40.0	7.5
# 12	TTY Component of # 9	2 minutes	19.6	4.0
# 13	MDCS Component of # 9	1 minute	37.6	10.0
# 14	No Data Calibration Situation	2 minutes	----	----

Data was collected for certain of the configurations listed on two separate occasions. Only a single result is shown because the existence of an unknown program error on one such occasion prevented the collection of valid data for the 490. Note also that for a combination of reasons including the referenced program error, valid data was not directly collected for two cases: a true peak traffic case for the 490 and in the case of the RTCC component of the peak traffic case. Valid results were collected, however, for a 490 peak traffic case excluding only RTCC traffic and for 494 peak traffic situations both with and without RTCC inputs. An assumption was made, therefore, to obtain certain results of the analysis: an increase in the 490 loading to reflect RTCC inputs was assumed to be proportional to the same increase measured for the 494. As a corollary, the RTCC component contribution to the sum of the parts (required to calculate X for the peak case) was estimated as being proportional to the relationship between the sum of all <u>other</u> parts and the measured loading for the 494 without RTCC inputs.

Data Reduction

After studying the characteristics of recorded data, it was determined that averaging of the measurements recorded for a single configuration would provide the most meaningful results. Averaging, however, was not accomplished for all data points associated with a particular configuration due to the large data reduction effort involved in converting counts recorded in octal to their decimal equivalent. (Note that incorporation of such a conversion capability as part of the tool itself would be highly desirable.)

Because of the importance of numeric loading results in the peak load cases, these results were achieved by averaging every fifth data point recorded (approximately 330 points in the measurement period). Results for all other configurations were generally achieved by averaging only two data points - the point for which the highest level of loading was recorded and that for which the lowest level was recorded. This simplification was employed because of a lesser interest in the actual result values. The inaccuracies involved were checked at random by averaging every third point in a few cases with the conclusion that the two point technique affected the result by approximately ± 1%. (± 1% of the result itself, not of the loading result obtained.) The results of the calibration measurements are an exception to the use of averaging as noted within the report itself.

Note that this analysis has established confidence that averaging of results is meaningful in most cases. This implies that data reduction effort may be reduced in the future by selecting a recording interval approximately equal to the period of measurement interest. Result: averaging automatically achieved.

Configurations Used to Support Figure 2-9

Configurations are identified below as associated with the particular interrupt rates providing data points for the interrupt rate vs. loading curve, Figure 2-9.

Interrupt Rate	Config.	Interrupt Rate	Config.
1/second	# 2	20/second	# 7
2	# 1, # 4 *	32	#11
4	# 3, # 5, # 10 *	36	# 8
10	# 6		

* These same combinations were used to achieve results relative to investigating loading sensitivity to detailed data characteristics as described in the main body of the report.

Configurations to Support Calculation of Overlap Form Factor (X)

The results of calculating X for the peak traffic situation are reflected in the main body of the report. Other configurations for which X was calculated are indicated below in terms of the additive relationship between certain configurations. Results are indicated as well.

Config. # 7 = Configs. # 3 + # 4 + # 6 + # 10

X = 0.346 for 494, 0.434 for 490

Config. # 8 = Config. # 10 + Config. # 11

X = 0.666 for 494, 0.8 for 490

APPENDIX C

This Appendix contains a bibliography of documents consulted in accomplishing the analysis reported in this Volume.II.

1. Goss Communication Network Data Book, PHO-1Z1000, 20 Oct. 1964, Vols. 3 and 4.
2. Goss Telemetry Network Data Book, PHO-1Z100, Vols. 1, 1A & 2.
3. Communications, Command and Telemetry System Specification, SS-03549A (Supersedes SS-03549, dated 29 Dec. 1965).
4. Goss Digital Command, Data Book, PHO-RT122, Vols. 1-3, July 1964.
5. Training Course, PCM/102A Ground Station, Lockheed Aircraft Co.
6. GTA-8 Telemetry Data Format Control Handbook, 13 Dec. 1966.
7. Univac document, "Univac 490 Communications Processing System, System Design Manual", plus amendments.
8. Univac document, "General Reference Manual for 494 System".
9. Bell Telephone Labs document MF5-4332-11, "Comm. Processor-Analysis of Char. Transfer Function", 31 March 1965.
10. Bell Telephone Labs document MF5-4332-54, "Comm. Processor-Analysis of Processing (P) Function", 22 Nov. 1965.
11. Bell Telephone Labs document MF5-4332-60, "Comm. Processor-Analysis of Storage Function", 27 Dec. 1965.
12. Radiation Melbourne document, "Technical Specification For Master Digital Command System", undated.
13. Radiation Melbourne document, "Master Digital Command System, Operation & Maintenance", Vols. I & II, November 1964.
14. Philco document PHO-TR181, "MCCH Telemetry, Command and Communication Augmentation Analysis for Apollo Program", undated.
15. Philco Specification No. SS-03549B, "Communications, Command and Telemetry System Specification", 5 April 1966.

APPENDIX D

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